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PATENT
Attorney Docket No.: COOL-01500

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:	Group Art Unit: 3744
Peng Zhou et al.	Examiner: Michael J. Early
Serial No.: 10/643,638	**TRANSMITTAL LETTER**
Filed: August 18, 2003	162 North Wolfe Road Sunnyvale, California 94086 (408) 530-9700
For: **BOILING TEMPERATURE DESIGN IN PUMPED MICROCHANNEL COOLING LOOPS**	Customer Number 28960

Mail Stop AF
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

Attached please find an Appeal Brief including a evidence appendix for filing with the U.S. Patent and Trademark Office. Also, attached is a check in the amount of $500.00 to cover the Appeal Brief fee.

The Commissioner is authorized to charge any additional fee or credit any overpayment to our Deposit Account No. 08-1275. **An originally executed duplicate of this transmittal is enclosed for this purpose.**

Respectfully submitted,
HAVERSTOCK & OWENS LLP

Dated: June 9, 2006

By: Jonathan O. Owens
Jonathan O. Owens
Reg. No.: 37,902

Attorneys for Applicants

CERTIFICATE OF MAILING (37 CFR§ 1.8(a))

I hereby certify that this paper (along with any referred to as being attached or enclosed) is being deposited with the U.S. Postal Service on the date shown below with sufficient postage as first class mail in an envelope addressed to the: Commissioner for Patents, P.O. Box 1450 Alexandria, VA 22313-1450

HAVERSTOCK & OWENS LLP.

Date: 6/9/06 By: [signature]

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In re Application of:	Group Art Unit: 3744
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Serial No.: 10/643,638	**APPEAL BRIEF**
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Sir:

In furtherance of the Applicants' Notice of Appeal filed on April 13, 2006, this Appeal Brief is submitted herewith. This Appeal Brief is submitted in support of the Applicants' Notice of Appeal filed on April 13, 2006, and further pursuant to the final rejection mailed on January 10, 2006. Claims 1-32 have been rejected. The Applicants submit this Appeal Brief to the Board of Patent Appeals and Interferences in compliance with the requirements of 37 C.F.R. § 1.192. The Applicants contend that the rejection of Claims 1-32 in this proceeding is in error and is overcome by this appeal.

I. REAL PARTY IN INTEREST

As the assignee of the entire right, title, and interest in the above-captioned patent application, the real party in interest in this appeal is:

Cooligy, Inc.
800 Maude Ave
Mountain View, CA 94043

Recently moved from:

2370 Charleston
Mountain View, CA 94043

This assignment results from the assignment documents recorded on August, 18, 2003 on reel number 014422, frame number 0898, and on November 24, 2003 on reel number 014720, frame number 0430.

II. RELATED APPEALS AND INTERFERENCES

The Applicants are not aware of any other appeals or interferences related to the present application.

III. STATUS OF THE CLAIMS

The pending U.S. Patent Application Serial Number 10/643,638 (the '638 patent application) was filed on August 18, 2003, and claims priority from U.S. Provisional Patent Application 60/455,729, filed on March 17, 2003.

A first Office Action was mailed on February 1, 2005, claims 1-32 were rejected. An Amendment and Response was filed on May 4, 2005, addressing the rejection of claims 1-32.

A second Office Action was mailed on August 9, 2005, withdrawing the rejection of the previous office action, and entering a new rejection of claims 1-32. An Amendment and Response was filed on November 11, 2005, addressing the rejection of claims 1-32.

A final Office Action was mailed on January 10, 2006, finalizing the rejection of claims 1-32. It is this rejection that is being contested in this appeal.

On February 15, 2006, Appellants had a telephone conference with the Examiner responsible for the application in which the Examiner agreed to secure an English translation of a Japanese reference and provide a copy to Appellants. On February 28, 2006, the Examiner faxed a copy of the translation to Appellants. Appellants assert that the translation supports the position that the claims distinguish over the prior art. In a telephone conversation, the Examiner told Appellants that the rejections of the Final Office Action would be maintained in spite of the translation.

The state of the claims is not at issue in this appeal; the claims included in the Appendix are consistent with the entered amendments made during the examination of the pending application. The rejection of Claims 1-32 is being appealed.

IV. STATUS OF THE AMENDMENTS

No amendments have been filed after the final Office Action mailed on January 10, 2006 The present condition of the claims is as listed in the Response filed on November 14, 2005.

V. SUMMARY OF THE CLAIMED SUBJECT MATTER

The instant invention is separately argued in the independent claim 1, and in dependent claims 2, 3, and 27

Claim 1 describes a method of cooling at least one heat-generating device using a cooling system. The method comprising the steps of: using at least one pump to cause a fluid to flow in at least one heat exchanger; and adjusting a pressure of the flowing fluid to correspondingly adjust a boiling point temperature of the fluid in the at least one heat exchanger.

Claim 2 describes a method of cooling at least one heat-generating device using a cooling system, as in claim 1, wherein the step of adjusting a pressure of the fluid comprises adjusting operating conditions of the at least one pump in response to at least one of the following: changes in pressure of the fluid; changes in temperature of the fluid; changes in temperature of the at least one heat-generating device; and changes in temperature of the at least one heat exchanger.

Claim 3 describes a method of cooling at least one heat-generating device using a cooling system, as in claim 1, wherein the step of adjusting a pressure of the fluid comprises adjusting an orifice coupled to the at least one heat exchanger in response to at least one of: changes in pressure of the fluid; changes in temperature of the fluid; changes in temperature of the at least one heat-generating device; and changes in temperature of the at least one heat exchanger.

VI. GROUNDS OF REJECTION TO BE REVIEWED ON APPEAL

The grounds of rejection for review by the Board of Patent Appeals and Interferences are as follows:

1. Claims 1 and 4 stand rejected 35 U.S.C. §103(a) as being unpatentable over Koo *et al.* "Modeling of Two-phase Microchannel Heat Sinks for VLSI Chips" ("Koo") in view of Japanese Patent No. JP 01-256775 to Yamaguchi ("Yamaguchi"); and
2. Claims 2, 27, and 28 stand rejected under 35 U.S.C. §103(a) as being unpatentable over Koo in view of Yamaguchi, and in further view of U.S. Patent No. 6,182,742 to Takahashi *et al.* ("Takahashi").
3. Claims 3, 14-21, 26, 31 and 32 stand rejected under 35 U.S.C. §103(a) as being unpatentable over Koo in view of Yamaguchi, and in further view of U.S. Patent Publication No. 2003/0121274 to Wightman *et al.* ("Wightman").
4. Claims 5-7 and 9-11 stand rejected under 35 U.S.C. §103(a) as being unpatentable over Koo in view of Yamaguchi, and in further view of U.S. Patent Publication No. 2004/0089008 to Tilton *et al.* ("Tilton").
5. Claim 8 stands rejected under 35 U.S.C. §103(a) as being unpatentable over Koo in view of Yamaguchi, and in further view of Tilton, and still further in view of U.S. Patent No. 6,775,996 to Cowans ("Cowans").
6. Claims 12 and 13 stand rejected under 35 U.S.C. §103(a) as being unpatentable over Koo in view of Yamaguchi, and in further view of U.S. Patent Publication No. 2004/0040695 to Chesser *et al.* ("Chesser").
7. Claims 22-25 stand rejected under 35 U.S.C. §103(a) as being unpatentable over Koo in view of Yamaguchi, and in further view of U.S. Patent No. 6,023,934 to Gold *et al.* ("Gold").
8. Claims 29 and 30 stand rejected under 35 U.S.C. §103(a) as being unpatentable over Koo in view of Yamaguchi, and in further view of Jiang *et al.* "A Closed-Loop Elecroosmotic Microchannel Cooling System for VLSI Chips" ("Jiang").

VII. ARGUMENT

The claims pending on appeal in this proceeding do not all stand or fall together.

Regarding the rejection of claims 1 and 4 under §103(a) as unpatentable over Koo in view of Yamaguchi: claims 1 and 4 stand or fall together.

Regarding the rejection of claims 2, 27, and 28 as unpatentable over Koo in view of Yamaguchi, in further view of Takahashi: claims 2, 27, and 28 do not stand or fall together because they contain different subject matter. Relevant to this rejection, claim 2 stands or falls separately from all other claims, and claims 27 and 28 stand or fall with claim 1.

Regarding the rejection of claims 3, 14-21, 26, 31 and 32 as unpatentable over Koo in view of Yamaguchi, in further view of Wightman: claims 3, 14-21, 26, 31 and 32 do not stand or fall together because they contain different subject matter. Relevant to this rejection, claims 3, 14-21, 26, 31 and 32 stand or fall with claim 1.

Regarding the rejection of claims 5-7 and 9-11 as unpatentable over Koo in view of Yamaguchi, in further view of Tilton: claims 5-7 and 9-11 stand or fall with claim 1.

Regarding the rejection of claim 8 as unpatentable over Koo in view of Yamaguchi, in further view of Tilton, in still further view of Cowans: claim 8 stands or falls with claim 1.

Regarding the rejection of claims 12 and 13 as unpatentable over Koo in view of Yamaguchi, in further view of Chesser: claims 12 and 13 stand or fall with claim 1.

Regarding the rejection of claims 22-25 as unpatentable over Koo in view of Yamaguchi, in further view of Gold: claims 22-25 stand or fall with claim 1.

Regarding the rejection of claims 29 and 30 as unpatentable over Koo in view of Yamaguchi, in further view of Jiang: claims 29 and 30 stand or fall with claim 1.

A. SUMMARY OF THE DIFFERENCES BETWEEN THE TECHNOLOGY OF THE PRIMARY REFERENCES AND THAT OF THE CLAIMED INVENTION

The present invention is directed toward a two-phase pumped cooling system. A heat exchanger is positioned to remove heat from a heat source. A heat rejector dispels heat from the system and into the ambient. A pump is used to actively move a cooling fluid through a cooling loop. **In each claim, the pressure of the fluid is adjusted to adjust the boiling point of the fluid in the pumped cooling system.**

There are two completely different cooling technologies taught in the references used to reject the claims and which are the subject of this appeal. The first cooling technology used to reject the claims is an "active" cooling system. The Koo reference, co-authored by inventors of the instant application, describes two-phase cooling in a system with a pump to move fluid around a cooling circuit. **There is no discussion regarding adjusting the pressure of the pumped fluid to adjust the boiling point.**

The second cooling technology used to reject the claims is a "passive" cooling system; **there is no pump**. Such devices are generally known in the art as "heat pipes." A passive cooling system typically employs a fluid and a wicking material sealed within a tube. Usually, one end of the heat pipe is mounted to a heat source. Fluid evaporates in the higher-temperature region and precipitates in lower temperature regions, facilitating heat transfer against the temperature gradient. There is no active pump to cause liquid to flow.

The Koo reference teaches only an active cooling system. However, **there is no teaching, hint or suggestion in Koo to adjust the pressure in the system for any purpose**. Thus, there is no teaching hint or suggestion to adjust the boiling point.

The Yamaguchi reference teaches cooling with both an active cooling system and a passive cooling system. Yamaguchi teaches adjusting the pressure in the passive cooling system, **only. There is no teaching, hint or suggestion in Yamaguchi to adjust the pressure in the active system.** There is no teaching in Yamaguchi for either cooling system nor in Koo, nor in the combination of Yamaguchi and Koo to adjust the pressure of a fluid in a pumped system to adjust the boiling point of the fluid.

B. DETAILED DISCUSSION - THE CLAIMS IN THE '638 APPLICATION ARE ALLOWABLE OVER THE REFERENCES CITED IN THE REJECTION.

1. Claim 1 is patentable over Koo in view of Yamaguchi.

According to both case law and procedure established by the U.S. Patent and Trademark Office, the burden falls on the examiner to establish a *prima facie* case for obviousness of a claim. See MPEP §2142 Citing *In re Rinehart*, 531 F.2d 1048, 189 USPQ 143 (CCPA 1976); *In re Linter*, 458 F.2d 1013, 173 USPQ 560 (CCPA 1972); *In re Saunders*, 444 F.2d 599, 170 USPQ 213 (CCPA 1971); *In re Tiffin*, 443 F.2d 394, 170 USPQ 88 (CCPA 1971), *amended*, 448 F.2d 791, 171 USPQ 294 (CCPA 1971); *In re Warner*, 379 F.2d 1011, 154 USPQ 173 (CCPA 1967), *cert. denied*, 389 U.S. 1057 (1968). To constitute a *prima facie* showing of obviousness over combined references, a rejection must meet three criteria: 1) the references themselves or the knowledge of one skilled in the art must provide some suggestion or motivation to combine reference teachings 2) one skilled in the art must view the combination as having reasonable expectation of success, and 3) the references must teach or suggest every limitation of the rejected claim. See MPEP §2142. In this application, the Examiner failed to present a *prima facie*

case for obviousness of claim 1, further, as described below, no such case can be made for the rejection over Koo in view of Yamaguchi.

a. Koo and Yamaguchi, in combination with the knowledge of one skilled in the art, do not provide the required motivation to combine their teachings.

In order to combine the teachings of two references, the references themselves must suggest the desirability of the claimed invention. See MPEP §2143.01(I) Citing *Al-Site Corp. v. VSI Int'l Inc.*, 174 F.3d 1308, 50 USPQ2d 1161 (Fed. Cir. 1999). In this case, the references disclose systems with differing principles of operation, and modifying the system of the primary reference Koo would require a change in the principle of operation of Koo. Further, the secondary reference Yamaguchi teaches away from the claimed invention. Finally, no teaching within Koo teaches that incorporating the system taught by Yamaguchi would yield any benefit.

i. Modifying Koo to incorporate the teachings of Yamaguchi would change the principle of operation of Koo, thus the two references do not constitute a *prima facie* case for obviousness.

An important criterion for establishing *prima facie* obviousness relates to the principles of operation of the various systems taught by the cited references. Namely, a suggested modification to a system taught by a reference is not sufficient to render claims *prima facie* obvious if it would require alteration of that system's principle of operation. See MPEP §2143.01(VI) Citing *In re Ratti*, 270 F.2d 810, 123 USPQ 349 (CCPA 1959). In the instant case, the modification to Koo proposed within the Final Office Action would require a change to the principle of operation of the system of Koo. To show that the proposed modification of Koo would change the system's principle of operation, the Appellants will first establish that the systems taught within Koo and Yamaguchi use different principles of operation. Then the Appellants will establish that the structural change made within the proposed modification would result in a device with a principle of operation different than that of Koo.

(A). Koo and Yamaguchi disclose systems with differing principles of operation.

The systems of Koo and Yamaguchi represent different approaches to the problem of cooling a heat producing device. Koo's system relies on a constantly flowing fluid to cool the device, while the system of Yamaguchi relies on flowing fluid to a certain extent, but uses a separately sealed evaporative cooling heat pipe to cool the device when the flowing fluid is insufficient.

(B). Koo discloses a cooling system with an active heat exchanger that uses a pumped fluid with no motivation to combine with a passive cooling element.

Figure 1 of Koo discloses an IC chip cooled by a microchannel heat exchanger through which fluid is pumped. The system uses a pump to cause fluid to flow in a heat exchanger. The fluid flowing through the heat exchange cools the IC chip.

(C). Yamaguchi discloses a cooling system with active and passive elements, but with no motivation to combine a passive element with an active cooling system.

Yamaguchi describes a "cooling device" with "two *independent* cooling units, liquid and evaporation cooling units." [Purpose, English Abstract (Appellant's emphasis)] An active liquid cooling unit circulates a refrigerant through a circulating pump (2). [Constitution, English Abstract (Appellant's emphasis)] A separate passive heat exchanger (4) for evaporative cooling is operative when the pump (2) is off; the passive heat exchanger includes a relief valve that "allows free adjustment of the boiling point of *the refrigerant for evaporation cooling* by changing the pressure of the refrigerant." [Constitution, English Abstract (Appellant's emphasis)] Yamaguchi's teaching of boiling point adjustments relates only to *evaporative* cooling that takes place within a passive heat exchanger (4A) separate from the circulated fluid heat exchanger. All advantages associated by Yamaguchi with adjusting the boiling point of fluid within a heat exchanger are associated with adjusting the boiling point only of a non-flowing refrigerant for evaporative cooling. Further, the separateness of the two cooling units within Yamaguchi urges a reader to view the two units as complimentary, but not to combine the two units. The Examiner has cited no teaching within Yamaguchi to the contrary, and indeed none exists.

(D). Modifying Koo to incorporate the teachings of Yamaguchi would change the principle of operation of Koo.

As outlined above, to the extent that Yamaguchi teaches adjusting the boiling point of a fluid, it concerns a non-flowing refrigerant for evaporative cooling. The system of Koo cools with a constantly flowing fluid. Incorporating non-flowing fluid cooling methods into the system of Koo would require a shift away from its principle of cooling with constantly flowing fluid.

ii. Yamaguchi teaches away from the claimed invention.

As mentioned above, Yamaguchi teaches that boiling point adjustments relate only to *evaporative* cooling that takes place within a passive heat exchanger (4) separate from a circulated fluid heat exchanger. Referring now to the English translation of Yamaguchi, both the

prior art device (FIGS. 5 and 6) and the invention of Yamaguchi (FIGS. 1-4) contain two *separate* cooling units. In FIG. 5, the water tanks (9) connect with the relief valve (5) to form a boiling and cooling system separate from the liquid cooling system.

It is stated within the translation that the "boiling and cooling" (evaporative) systems operate at "higher cooling performance" than the liquid system. However, all advantages associated by Yamaguchi with adjusting the boiling point of fluid within a heat exchanger are associated with adjusting the boiling point only of a non-flowing refrigerant for evaporative cooling. No association is made between the cooling mechanisms of the flowing and non-flowing refrigerants within the cited portion of Yamaguchi.

Further, the separateness of the two cooling units within Yamaguchi urges a reader to view the two units as complimentary, but not to combine the two units. The Examiner has cited no teaching within Yamaguchi to the contrary, and indeed none exists. Apparently, the Examiner relies on Koo to overcome these teachings of Yamaguchi.

iii. <u>No particular teaching within Koo teaches that incorporating the system taught by Yamaguchi would yield any benefit</u>

The Examiner has not pointed out any teachings within Koo that suggest incorporating a boiling point adjustment means within its system. The various justifications for combining Koo with Yamaguchi provided by the Examiner have been unpersuasive.

Within the Final Office Action, the Examiner admits the following:

> [The] argument [that Yamaguchi does not teach, hint or suggest that the flowing fluid pressure be adjusted to correspondingly adjust the boiling point temperature of the fluid] is correct; however, the combination of Koo et al. in view of Yamaguchi does provide this teaching.

To illustrate this point, the Examiner states that "Although Yamaguchi teaches of stopping a circulating pump before allowing the boiling point of the refrigerant to be adjusted by the pressure of the refrigerant [*sic*], Koo et al. disclose of a method of cooling a heat-generating device with a pump ***to cause a fluid to flow*** in a heat exchanger..." (emphasis in original). Unfortunately, the Examiner apparently ignores Appellants attempts to point out that the circulating pump in Yamaguchi affects a *different fluid* than the boiling point adjustment valve of Yamaguchi. [Response to Office Action, Pg. 7, Ll. 16-17] Further, the Examiner does not explain his need to rely on Koo when Yamaguchi also teaches using a pump to cause fluid to flow.

Also within the Final Office Action, the Examiner mentions that "Koo et al. further disclose that both the pressure drop and pump power are dependent upon the mass flowrate of the flowing fluid within the system." However, the Examiner provides no explanation of how this

teaching relates to the boiling point of the flowing fluid. Appellants submit that the Examiner may be confusing 'pressure drop' of a system with 'pressure' of a fluid within the system. The terms refer to different concepts: the 'pressure drop' of a system is the differential pressure that a fluid must overcome to flow through that system; the 'pressure' of a fluid within a system is the ratio of the force exerted by the fluid on the inner surface of the system, divided by the inner surface area.

iv. The teachings of Koo and Yamaguchi, when presented to one skilled in the art as of the filing date of the Appellants application would not suggest the desirability of the inventions recited in <u>claim 1 to one skilled in the art.</u>

The Examiner's failure to point out any specific teaching within Koo, or the knowledge of one skilled in the art, that motivates combination with Yamaguchi militates against a conclusion of *prima facie* obviousness. <u>See</u> MPEP §2143.01(I). This is especially true since the teachings of Yamaguchi cut against the combination as described above. <u>See</u> MPEP §2143.01(II)

However, additional factors weigh against the combination of the two references. Of course, Koo doesn't anticipate the claims at issue, a notion supported by the Examiner's rejections. The authors of Koo either considered the claims at issue trivial variations of the model they describe or they did not consider them at all. However, the reference Koo includes inventors of the present invention among its authors, Koo was published in January of 2001, and the present invention has a priority date of March 17, 2003. This set of facts implies that the inventors who authored Koo considered to be non-obvious in view of Koo.

v. On the effective filing date of the '638 application, one skilled in the art would have no motivation to combine the teachings of Koo <u>and Yamaguchi to produce the inventions recited in claim 1.</u>

Therefore, because modifying Koo as proposed would change its principle of operation, because Yamaguchi teaches away from the proposed combination, and because no teaching of Koo has been shown to suggest the proposed combination, the combination of Koo and Yamaguchi does not include any motivation to one skilled in the art. Hence, the rejection of claim 1 does not constitute a *prima facie* case for obviousness.

b. The combination of Koo in view of Yamaguchi does not teach or suggest <u>*every* limitation of claim 1</u>

Furthermore, even if the system taught by Koo were modified with the teaching of Yamaguchi, the resulting system would not contain every limitation of claim 1. To constitute a

prima facie case for obviousness, a combination of references must teach or suggest every limitation of a claim. See MPEP §2143.03, Citing *In re Royka*, 490 F.2d 981, 180 USPQ 580 (CCPA 1974).

i. Koo teaches an active cooling system in which a pump causes fluid to flow within a heat exchanger to cool a heat-generating device coupled with the heat exchanger.

As described above, the system within Koo is an active cooling system that uses a constantly flowing fluid to cool a heat producing device.

ii. Yamaguchi teaches a system with active and passive elements: in the passive element, the boiling point of a refrigerant for evaporative cooling can be adjusted, but the refrigerant is not caused to flow by a pump.

Also as described above, the system taught within Yamaguchi contains two independent cooling units: an active cooling unit that uses a flowing fluid, and a passive unit that relies on evaporation of a refrigerant. During use of the refrigerant, flow within the active cooling unit is stopped. [English translation, Pg. 4, 2nd paragraph] Though the boiling point of the refrigerant within the passive unit may be freely adjusted, the advantages associated with this adjustment are taught with reference to an passive cooling system with non-flowing fluid.

iii. The incorporation of a passive element with an adjustable boiling point, as taught by Yamaguchi, into the active cooling system taught by Koo does not produce the claimed invention.

If, given the various advantages taught by Yamaguchi, someone were to perform a method of cooling that combined attributes of the active cooling system of Koo with those of the passive cooling unit of Yamaguchi, it would be a method in which the flowing fluid were *stopped* prior to adjusting the boiling point of the flowing fluid. Since the claim 1 recite "adjusting a pressure of the flowing fluid" the method suggested by the combination of Koo with Yamaguchi is not the claimed invention.

c. For at least the reasons given above, claim 1 is allowable over Koo in view of Yamaguchi.

Koo and Yamaguchi do not constitute a *prima facie* case for obviousness of claim 1. The Examiner did not point out particular teachings within either of the references to overcome Appellants objection to the rejection. For the reasons described above, the rejection is improper and should be withdrawn.

As stated above, claims 3-32 stand or fall with claim 1. Since claim 1 is non-obvious, its dependent claims are also. See MPEP §2143.01 The various additional references used in rejection of these claims are moot and will not be discussed herein, with the exception of those references used in the rejection of claim 2.

2. Claim 2 is patentable over Koo in view of Yamaguchi as applied to claim 1 and further in view of Takahashi.

Claim 2 depends from claim 1. As discussed above, claim 1 is non-obvious. Since claim 1 is non-obvious, its dependent claims are also. See MPEP §2143.01 However, for additional reasons, claim 2 is separately patentable from claim 1.

a. The combination of Koo in view of Yamaguchi and further in view of Takahashi does not teach or suggest *every* limitation of claim 2

Even assuming that Koo in view of Yamaguchi did teach every limitation of claim 1, modification of that system by the teachings of Takahashi would not contain every limitation of claim 2. To constitute a *prima facie* case for obviousness, a combination of references must teach or suggest every limitation of a claim. See MPEP §2143.03, Citing *In re Royka*, 490 F.2d 981, 180 USPQ 580 (CCPA 1974).

i. Takahashi teaches switching a pump between an operating mode and a standby mode in response to temperature sensors, but does not teach adjusting the pressure of the operating fluid.

The portion of Takahashi cited within the Final Office Action relates to a cooling system containing multiple cooling units (1100A and 1100B of FIG. 1), each of which has a pump (1110A and 1110B respectively). The cooling units, and in turn their pumps, are placed on either standby or operating mode by controllers (1140A and 1140B respectively). Each controller has fluid temperature as an input, as sensed by temperature sensors (1300A and 1300B respectively).

In some circumstances, a controller signals a pump to stop or start in response to temperature conditions. However, there is no teaching or suggestion that this stopping or starting of the pump affects fluid pressure within the system, or that pressure within the system is important. Instead, Takahashi focuses on temperature within the system, but even then, the pump alone is not responsible for regulating temperature. Temperature is regulated by a combination of the pump with a three-way valve (e.g. 1130A). [Col. 3, Ll. 33-45]

ii. Accordingly, the combination of Takahashi with Koo in view of Yamaguchi does not render claim 2 obvious.

Since no connection between system fluid pressure and pump operating conditions is drawn within Takahashi, there is no sense in which Takahashi discloses "the pressure of the refrigerating fluid is adjusted in the system by adjusting the operating conditions of the pump in response to the change in the temperature of the fluid" as alleged within the Final Office Action. Therefore, the rejection of claim 2 does not constitute a *prima facie* case for obviousness. The For the reasons described above, the rejection is improper and should be withdrawn.

C. CONCLUSION

For the above reasons, it is respectfully submitted that the claims 1-32 are allowable over the cited prior art references. Therefore, a favorable indication is respectfully requested.

VIII. CLAIMS APPENDIX

Below is a true and accurate listing of the claims involved in this appeal.

1. A method of cooling at least one heat-generating device using a cooling system, the method comprising the steps of:
using at least one pump to cause a fluid to flow in at least one heat exchanger; and
adjusting a pressure of the flowing fluid to correspondingly adjust a boiling point temperature of the fluid in the at least one heat exchanger.

2. The method of claim 1, wherein the step of adjusting a pressure of the fluid comprises adjusting operating conditions of the at least one pump in response to at least one of:
    changes in pressure of the fluid;
    changes in temperature of the fluid;
    changes in temperature of the at least one heat-generating device; and
    changes in temperature of the at least one heat exchanger.

3. The method of claim 1, wherein the step of adjusting a pressure of the fluid comprises adjusting an orifice coupled to the at least one heat exchanger in response to at least one of:
    changes in pressure of the fluid;
    changes in temperature of the fluid;
    changes in temperature of the at least one heat-generating device; and
    changes in temperature of the at least one heat exchanger.

4. The method of claim 1, wherein the method further comprises the step of: providing at least one heat rejector for rejecting heat from the system to ambient air, the at least one heat rejector being situated downstream of the at least one heat exchanger.

5. The method of claim 4, wherein the method further comprises the step of providing a reservoir that accommodates a larger volume of a gas in the system generated during boiling.

6. The method of claim 5, wherein the reservoir reduces a change in pressure of the fluid that occurs during boiling.

7. The method of claim 5, wherein the reservoir is situated downstream of the at least one heat rejector.

8. The method of claim 5, wherein the reservoir is situated upstream of the at least one heat rejector.

9. The method of claim 5, wherein the reservoir having a volume region as great as the volume of vapor generated by the at least one heat exchanger during boiling of the fluid.

10. The method of claim 5, wherein the reservoir having an inlet coupled to a fluid outlet port of the at least one heat rejector via a first portion of a fluid transport line and an outlet coupled to a fluid inlet port of the at least one pump via a second portion of the fluid transport line.

11. The method of claim 5, wherein the reservoir is integrated with one of the at least one heat rejector and the at least one pump.

12. The method of claim 1, wherein the system is hermetically sealed.

13. The method of claim 12, wherein the hermetically sealed refers to a design in which the pressure under a given set of pump, ambient temperature, and heating conditions varies by less than 1 psi during a five year lifetime.

14. The method of claim 1, wherein the fluid is selected from a group consisting of water, acetonitrile, acetone, N-methylformamide, benzene, ethanol, methanol, and a combination thereof.

15. The method of claim 1, wherein the fluid comprises a halocarbon.

16. The method of claim 15, wherein the halocarbon is a methane series halocarbon selected from the group consisting of trichlorofluoromethane and trifluoromethane.

17. The method of claim 15, wherein the halocarbon is a ethane series halocarbon comprising pentafluoroethane (R-125).

18. The method of claim 1, wherein the fluid is a zeotropic blend comprising R-404A.

19. The method of claim 1, wherein the fluid is an azeotropic blend selected from the group consisting of R-500 and R-502.

20. The method of claim 1, wherein the fluid is inorganic.

21. The method of claim 20, wherein the inorganic is selected from the group consisting of ammonia and carbon dioxide.

22. The method of claim 1, wherein the fluid comprises a hydrocarbon.

23. The method of claim 22, wherein the hydrocarbon is selected from the group consisting of methane, ethane, propane, n-butane, 2-methylpropane, isobutane, ethene, ethylene, propene, propylene, and combinations thereof.

24. The method of claim 1, wherein the fluid is cryogenic.

25. The method of claim 24, wherein the cryogenic is selected from the group consisting of hydrogen, parahydrogen, helium, nitrogen, neon, air, oxygen, argon, and combinations thereof.

26. The method of claim 1, wherein the fluid is selected from the group consisting of water, acetonitrile, acetone, N-methylformamide, benzene, ethanol, methanol, halocarbons, zeotropic blends, azeotropic blends, inorganic fluids, hydrocarbons, cryogenic fluids, and mixtures thereof, the halocarbons being methane series halocarbons selected from the group consisting of trichlorofluoromethane, trifluoromethane and mixtures thereof, the

zeotropic blends comprising R-404A, the azeotropic blends being selected from the group consisting of R-500, R-502 and mixtures thereof, the inorganic fluids being selected from the group of ammonia, carbon dioxide and mixtures thereof, the hydrocarbons being selected from the group consisting of methane, ethane, propane, n-butane, 2-methylpropane, isobutane, ethene, ethylene, propene, propylene and mixtures thereof, the cryogenic fluids being selected from the group consisting of hydrogen, parahydrogen, helium, nitrogen, neon, air, oxygen, argon and mixtures thereof.

27. The method of claim 1, wherein the method further comprises the step of: providing sensors to adjust the fluid flow from the at least one pump.

28. The method of claim 27, wherein the sensors being coupled to the at least one heat exchanger.

29. The method of claim 1, wherein the at least one pump is electro-osmotic.

30. The method of claim 1, further comprising the step of: delivering to a catalytic recombiner a gaseous stream containing hydrogen being discharged from a downstream side of the at least one pump together with an amount of oxygen generated from an upstream side of the at least one pump sufficient to convert the hydrogen and oxygen to water, the catalytic recombiner coupled to an inlet port of the at least one pump.

31. The method of claim 1, wherein the step of adjusting a pressure of the fluid comprises adjusting the pressure of the fluid during a charging and sealing of the system.

32. The method of claim 1, wherein the step of adjusting a pressure of the fluid comprises adjusting at least one of a composition and volume and combinations thereof of at least one of a gas and liquid and combinations thereof introduced during charging of the system.

IX. EVIDENCE APPENDIX

Pursuant to 37 C.F.R. § 41.37(c)(1)(ix), the following is a statement setting forth where in the record the evidence of this appendix was entered by the examiner:

Evidence Description:	**Where Entered:**
Original Specification	Examiner Office Action mailed May 6, 2004
Jae-Mo Koo *et al.*, "Modeling of Two-Phase Microchannel Heat Sinks for VLSI Chips", Mech. Eng. Depart. of Stanford University, pp. 422-426	Examiner Office Action mailed February 1, 2005
Japanese Patent No. JP 01-256775 *including* English Abstract	In the "Notice of References Cited" included with the Office Action mailed on August 9, 2005
Response to Office Action	Examiner Office Action mailed January 10, 2006
Office Action mailed January 10, 2006	Examiner Office Action
English Translation of Japanese Patent No. JP 01-256775	Examiner Fax dated February 28, 2006
Interview Summary	Examiner Interview Summary mailed Februrary 22, 2006

X. RELATED PROCEEDINGS APPENDIX

There are no related proceedings.

Respectfully submitted,
HAVERSTOCK & OWENS LLP

Dated: June 9, 2006

By: Jonathan O. Owens
Jonathan O. Owens
Reg. No.: 37,902

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CERTIFICATE OF MAILING (37 CFR§ 1.8(a))

I hereby certify that this paper (along with any referred to as being attached or enclosed) is being deposited with the U.S. Postal Service on the date shown below with sufficient postage as first class mail in an envelope addressed to the: Commissioner for Patents, P.O. Box 1450 Alexandria, VA 22313-1450

HAVERSTOCK & OWENS LLP.

Date: 6/9/06 By: [signature]

BOILING TEMPERATURE DESIGN IN PUMPED MICROCHANNEL COOLING LOOPS

Related Application

This application claims priority under 35 U.S.C. § 119(e) of the co-pending U.S. provisional patent application Serial Number 60/455,729, filed on March 17, 2003, and titled "Microchannel Heat Exchanger Apparatus with Porous Configuration and Method of Manufacturing Thereof." The provisional patent application Serial Number 60/455,729, filed on March 17, 2003, and titled "Microchannel Heat Exchanger Apparatus with Porous Configuration and Method of Manufacturing Thereof" is hereby incorporated by reference.

Field of the Invention

This invention relates generally to removal of heat from heat generating devices. More specifically, this invention relates to use of pressure in a heat exchanger within a closed loop cooling system such that fluid temperature will be ideal for removing heat from heat generating devices at a targeted temperature.

Background of the Invention

A variety of devices and applications are present which require cooling of devices that have very high heat fluxes, such as in the range of 30-1000 W/cm^2. These devices include integrated electronic circuits in microprocessors, laser diodes, and power semiconductor devices for control electronics. There have been many solution strategies for cooling these devices.

One solution strategy for cooling a device emitting high heat fluxes includes utilizing a vapor chamber or a heat pipe 10, as shown in Figure 1A. The heat pipe 10 includes a wick structure 14 which draws liquid to the heat source 99 by the use of capillary forces. In particular, as shown in Figure 1A, the liquid evaporates in the wick 14 when heated and the resulting vapor

escapes to the center of the heat pipe 10 where it is propelled to cooler regions for condensation. However, a problem with the geometry of the heat pipe 10 is that the flowrate of the liquid is limited by the capillary pressure available for drawing liquid back into the wick 14. One way to increase the flowrate of liquid through the heat pipe 10 is to make the wick structure 14 thicker. However, thickening the wick structure 14 increases the heat transfer resistance for conduction normal to the wick structure 14 itself, thereby rendering the wick 14 less effective. The temperature rise between the heat inlet and the heat exchange interface would increase if a thickened wick 14 is used, thereby making the heat pipe 10 less effective.

Another solution strategy for cooling the high heat fluxes in the devices is using a microchannel heat sink 20 coupled to a pump 22 and a heat rejector 26, as shown in Figure 1B. This approach in Figure 1B can achieve a much higher liquid flowrate per unit volume than heat pipes 10 (Figure 1A) due to the presence of the pump. This approach increases the heat removal capacity of the heat sink 20 without increasing the system volume. The heat transfer resistance remains low, because the resistance is governed by the small hydraulic diameter and large surface-to-volume ratio of the microchannels 24 in the heat sink 20, which remains the same. Microchannel heat sinks 20 with two-phase boiling convection achieve high rates of cooling with relatively low flowrates through evaporation of the fluid.

However, a problem with cooling a device using these two-phase microchannel heat exchangers is the large pressure gradients that occur along the channels when the liquid begins to boil. It is known that the vapor phase of a substance is much less dense than that of the substance in liquid form. Therefore, for a given pumping power, the vapor phase of the substance will accelerate through a channel by up to a factor of a 1000 times. The acceleration and the resulting shear forces of the vapor substance through the channel dramatically increases the pressure drop along the channel. The large pressure drop in the channel thereby causes two-phase unsteady flow instabilities along the channel. These instabilities are associated with and aggravated by bubbles forming in the flow and large drag forces being produced due to the small dimensions of the channels. The large pressure drop also greatly increases the amount of power

required to pump the liquid through the microchannel heat sink 20. In effect, the microchannel requires more pumping power to cool a device 99, because the boiling of the liquid causes a very large increase in volume flow rate and a large pressure drop within the microchannel heat sink 20.

What is needed is a method of and apparatus for controlling fluid pressure to achieve a targeted boiling temperature within a heat exchanger of a cooling system.

Brief Summary of the Invention

According to a first aspect of the present invention, a method of cooling a heat-generating device uses a cooling system. The method comprises the steps of: using at least one pump to cause a fluid to flow in at least one heat exchanger; and adjusting a pressure of the fluid to correspondingly adjust a boiling point temperature of the fluid in the at least one heat exchanger. The system can be hermetically sealed. The at least one pump can be electro-osmotic.

The step of adjusting a pressure of the fluid can include adjusting operating conditions of the at least one pump in response to at least one of: changes in pressure of the fluid; changes in temperature of the fluid; changes in temperature of the at least one heat-generating device; and changes in temperature of the at least one heat exchanger. Alternatively, the step of adjusting a pressure of the fluid can include adjusting an orifice coupled to the at least one heat exchanger in response to at least one of: changes in pressure of the fluid; changes in temperature of the fluid; changes in temperature of the at least one heat-generating device; and changes in temperature of the at least one heat exchanger. Further, the step of adjusting a pressure of the fluid can include utilizing a flexible volume reservoir or membrane that controllably expands or contracts. The step of adjusting a pressure of the fluid can comprise adjusting a composition and volume of a gas and liquid introduced during charging of the system. The step of adjusting a pressure of the fluid can also comprise adjusting a pressure of the fluid during charging and sealing of the system.

The method can further comprise the step of providing at least one heat rejector for

rejecting heat from the system. The at least one heat rejector can be situated downstream from the at least one heat exchanger.

The method can further comprise the step of providing a reservoir that accommodates a large volume of gas in the system during boiling. The reservoir can reduce a change in pressure of the fluid that occurs during boiling. The reservoir can be situated downstream of the at least one heat rejector. Alternatively, the reservoir can be situated upstream of the at least one heat rejector. Preferably, the reservoir has a volume region as great as the volume of vapor generated by the at least one heat exchanger during boiling of the fluid. Preferably, the reservoir has an inlet coupled to a fluid outlet port of the at least one heat rejector via a first portion of a fluid transport line and an outlet coupled to a fluid inlet port of the at least one pump via a second portion of the fluid transport line. The reservoir can also be integrated with the heat rejector or the pump.

The fluid can be selected from a group consisting of water, acetonitrile, acetone, N-methylformamide, benzine, ethanol, methanol, any other fluids or a combination thereof. The fluid can also comprise a halocarbon or methane series halocarbon, including trichlorofluoromethane and trifluoromethane. Alternatively, the fluid can comprise a ethane series halocarbon, such as pentafluoroethane, and other halocarbons from the group consisting of methane, ethane, propane, n-butane, 2-methylpropane, isobutane, ethene, ethylene, propene, propylene, and combinations thereof. The fluid can also comprise zeotropic blends, such as R-404A, Azeotropic blends, such as R-500 and R-502, and inorganic fluids, including ammonia and carbon dioxide. Further, the fluid can be a cryogenic fluid selected from the group consisting of hydrogen, parahydrogen, helium, nitrogen, neon, air, oxygen, argon, and combinations thereof.

The method can further comprise the step of providing sensors, such as temperature or pressure sensors, to control the fluid flow from the at least one pump. The sensors can be coupled to the at least one heat exchanger.

The method can further comprise the step of delivering to a catalytic recombiner a gaseous stream containing hydrogen being discharged from a downstream side of the at least one

pump together with an amount of oxygen generated from an upstream side of the at least one pump sufficient to convert the hydrogen to water. The catalytic recombiner can be coupled to an inlet port of the at least one pump.

Brief Description of the Several Views of the Drawings

Figure 1A illustrates a schematic diagram of an existing heat pipe including the wick structure for the liquid and vapor region.

Figure 1B illustrates a schematic diagram of an existing microchannel cooling loop including the pump and the thin channel region for the fluid.

Figure 2 illustrates a cooling system used to cool a heat generating device in accordance with the present invention.

Figure 3 illustrates a schematic diagram of a cooling system under steady state conditions in accordance with the present invention.

Figure 4A is a schematic flow chart illustrating steps of a preferred method of the present invention.

Figure 4B is a schematic flow chart illustrating steps of an alternative method of the present invention.

Figure 5 illustrates a schematic diagram of a preferred embodiment of the reservoir, including a free volume region, in accordance with the present invention.

Figure 6 illustrates a schematic diagram of a cooling system, including an electroosmotic pump that generates hydrogen and oxygen, with means for recombining the gases at the pump inlet.

Figure 7A is a schematic flow chart illustrating steps of an alternative method of the present invention.

Figure 7B is a schematic flow chart illustrating steps of an alternative method of the present invention.

Figure 7C is a schematic flow chart illustrating steps of an alternative method of the

present invention.

Figure 8 illustrates a schematic diagram of an alternative system of the present invention.

Detailed Description of the Invention

Reference will now be made in detail to the preferred and alternative embodiments of the invention, examples of which are illustrated in the accompanying drawings. While the invention will be described in conjunction with the preferred embodiments, it will be understood that they are not intended to limit the invention to these embodiments. On the contrary, the invention is intended to cover alternatives, modifications and equivalents, which may be included within the spirit and scope of the invention as defined by the appended claims. Furthermore, in the following detailed description of the present invention, numerous specific details are set forth in order to provide a thorough understanding of the present invention. However, it should be noted that the present invention may be practiced without these specific details. In other instances, well known methods, procedures and components have not been described in detail as not to unnecessarily obscure aspects of the present invention.

Figure 2 illustrates a schematic diagram of a cooling system 200, which can be a hermetically sealed loop, in accordance with the present invention. The cooling system 200 comprises a microchannel heat exchanger 210, in which a fluid absorbs heat from a heat-generating device 220, a heat rejector 230, which transfers heat from the fluid to a surrounding ambient environment, and a pump 240, which propels the fluid into the heat exchanger 210 and provides a necessary pressure drop for the heat exchanger 210. For purposes of this disclosure, the heat exchanger 210 can contain internal flow regions or microchannels 215 with walls separated by less than 1 mm, with wall separations in a range between 4 micrometers and 500 micrometers. The microchannels 215 of the heat exchanger 210 can be oriented horizontally, vertically or at some other angle, or with combinations of these orientations. Manifolds delivering fluid to the microchannels 215 and removing the fluid from the microchannels 215 can include multiple inlet and outlet regions. The fluid can be defined as any liquid and gas existing

in the system 200. The fluid travels through the system 200 via a fluid transport line 250. When the pump 240 is turned off, pressure will be uniform around the system 200. This uniform pressure, also referred to as a "stationary loop pressure," depends on ambient temperature.

Figure 3 is a schematic diagram of a cooling system 300 under steady state conditions. Immediately after a pump 305 is turned on during steady-state conditions, pressure will be at its lowest at an inlet 310 of the pump 305. Pressure will be at its highest at an outlet 320 of the pump 305. A goal of the present invention is to use pressure to control a boiling point temperature of the fluid in a heat exchanger 330. This pressure, which, under appropriate conditions, will occur within some region within the heat exchanger 330, will influence a maximum temperature in a heat-generating device. When the heat generating device is a semiconductor integrated circuit, this pressure will influence the maximum temperature of elements in the circuit. At low flow rates, the pressure of boiling onset will be nearly equal to an inlet pressure of the heat exchanger 330. At high flow rates, the pressure of boiling onset will be closer to an outlet pressure of the heat exchanger 330. Alternatively, boiling pressure can be intermediate between the inlet pressure and the outlet pressure.

When liquid boils, it absorbs more heat through vaporization than the liquid will absorb when not boiling. In a pumped loop, the boiling fluid creates a vapor whose volume raises the pressure of the loop. By controlling the boiling point temperature of the fluid in a heat exchanger, the system effectively controls a temperature of a heat-generating device. A goal of this invention is to adjust a pressure of the fluid in the heat exchanger to achieve a targeted boiling temperature to effectively cool the heat-generating device to a desired temperature. Specifically, this pressure can be a maximum pressure at which boiling occurs. The pressure of the fluid in the heat exchanger can be adjusted during charging and sealing of the system. The terms charging and sealing, as used in the present invention, can be defined as the act of filling a system with liquid and gas and sealing the system at a targeted pressure. Further, a composition and volume of the liquid and gas introduced during the charging of the system can be adjusted to adjust a pressure of the fluid in the heat exchanger.

In one embodiment of the present invention, a method of cooling a heat-generating device uses a cooling system, as shown in Figure 4A. In the step 400, a pump is used to cause a fluid to flow in a heat exchanger. In the step 410, operating conditions of the pump are adjusted in response to changes in pressure of the fluid to correspondingly adjust a boiling point temperature of the fluid. The method can further include the step of providing a heat rejector for rejecting heat from the system, the heat rejector being situated downstream of the heat exchanger, as shown in Figure 2.

The method can also include the step of providing a reservoir 500, as shown in Figure 5, that accommodates a larger volume of gas in the system 200 (figure 2) generated during boiling. The reservoir 500 can be situated downstream of the heat exchanger 210 (Figure 2) and have a volume region 540 at least as large as the volume of vapor generated by the heat exchanger 210 (Figure 2) during boiling of the fluid at targeted pressure conditions. In a pumped loop, as in Figure 2, boiling fluid creates a vapor whose volume raises the pressure of the entire loop, particularly downstream of the heat exchanger 210 (Figure 2) and the heat rejector 230 (Figure 2). Specifically, the vapor will occupy volume from some region within the heat exchanger 210 (Figure 2), where the fluid starts boiling, and some region within the heat rejector 230 (Figure 2), where the fluid is fully condensed. This region, from boiling onset to full condensation, occupies a volume, V, which can include the fluid transport line 250 (Figure 2) between the heat exchanger 210 (Figure 2) and the heat rejector 230 (Figure 2). Just as occurs in a "pressure-cooking device," the generation of a vapor will increase overall pressure in the loop. The reservoir 500 can reduce a change in pressure of the fluid that occurs during boiling. To achieve a stable operating pressure, the loop must be designed with sufficient free volume before boiling starts to accommodate this increase in volume without exceeding a targeted pressure. Therefore, the free volume 540 of the reservoir 500 includes at least the volume, V, which is equal to the sum of a volume of the heat exchanger 210 (Figure 2) and a volume of the heat rejector 230 (Figure 2) and a volume of the fluid transport line 250 (Figure 2) in between the heat exchanger 210 (Figure 2) and the heat rejector 230 (Figure 2). When the system 200 (Figure 2) is loaded

initially, the free volume 540 can be located anywhere in the loop and will contain low pressure gas.

As shown in Figure 5, the reservoir 500 can have an inlet 510 coupled to a fluid outlet port of the heat rejector 230 (Figure 2) via a first portion of the fluid transport line 250 (Figure 2) and an outlet 520 coupled to a fluid inlet port of the pump 240 (Figure 2) via a second portion of the fluid transport line 250 (Figure 2). Alternatively, the reservoir 500 can be integrated with the heat rejector 230 (Figure 2) or the pump 240 (Figure 2).

As mentioned above, the relevant pressure to be controlled is that in the heat exchanger 210 (Figure 2) at the onset of boiling. Since this targeted pressure will be discerned at some position in the heat exchanger 210 (Figure 2), it will be helpful to minimize pressure drop downstream of the heat exchanger 210 (Figure 2). If there is a large pressure drop downstream of the heat exchanger 210 (Figure 2), it can be difficult to achieve a targeted pressure at boiling onset without requiring a negative (unphysical) pressure at an outlet of the heat rejector 230 (Figure 2). Therefore, this invention covers a variety of methods of achieving low pressure drops in the heat rejector 230 (Figure 2).

In order to achieve a targeted heat source temperature, a boiling point temperature of the fluid in the heat exchanger 210 (Figure 2) can be controlled. This invention covers all fluids operating in a cooling system 200 (Figure 2) with pressure chosen for the boiling point temperature. Preferably, the pressure chosen will be below atmospheric pressure. Preferably, the fluid will consist of water with additives in the cooling system 200 (Figure 2). However, since fluid and fluid mixtures have boiling points that are functions of pressure, many different fluids can be used in the cooling system 200 (Figure 2). For example, the fluid can consist of water, ammonia, acetone, acetonitrile, N-methylformamide benzene, ethanol, methanol or mixtures of multiple substances. In certain cases, the fluid can consist of a nearly pure substance with small quantities of an impurity, such as a buffer, which assists in the operation of other components in the cooling system 200 (Figure 2) such as the pump 240 (Figure 2). In other cases, the fluid can also comprise a halocarbon or methane series halocarbon, including trichlorofluoromethane and

trifluoromethane. Alternatively, the fluid can comprise a ethane series halocarbon, such as pentafluoroethane, and other halocarbons from the group consisting of methane, ethane, propane, n-butane, 2-methylpropane, isobutane, ethene, ethylene, propene, propylene, and combinations thereof. The fluid can also comprise zeotropic blends, such as R-404A, azeotropic blends, such as R-500 and R-502, and inorganic fluids, including ammonia and carbon dioxide. Further, the fluid can be a cryogenic fluid selected from the group consisting of hydrogen, parahydrogen, helium, nitrogen, neon, air, oxygen, argon, and combinations thereof. It should be noted that the fluid can consist of mixtures of all of the above-mentioned fluids.

To help maintain a proper pressure in the heat exchanger 210 (Figure 2), specifically at a location of boiling onset, operating conditions of the pump 240 (Figure 2) flow rate can be adjusted by adjusting a level of an AC voltage 270, DC voltage 275 or other governing input to the pump 240 (Figure 2). This invention covers use of a pump to control a boiling point of the fluid. Sensors 290 can be provided to adjust the fluid flow rate from the pump 240 (Figure 2). The sensors 290 can be positioned downstream and/or upstream of the heat exchanger 210 (Figure 2). Alternatively, the sensors 290 can be temperature sensors downstream and/or upstream of the heat exchanger 210 (Figure 2). The sensors 290 can further be integrated with the heat exchanger 210 (Figure 2) using fabrication techniques.

Although a variety of pumping mechanisms can be used to implement the present invention, pumping of fluids by pumps based on electroosmosis is particularly promising for a hermetically sealed cooling system because it provides robust sealing and reliability. On the other hand, electroosmotic pumps generate gas at an anode and cathode. These gases increase pressure in the system, although this effect can be minimized through efficient recombination of the gases using catalysis. This invention covers a design of a free volume in a pump to include a balance of gases generated at the anode and cathode of the pump to achieve a steady state concentration and pressure contribution due to the generated gases. In one embodiment, as shown in Figure 6, hydrogen generated on a downstream side 610 of a pump 600 travels around a loop 620, through a heat exchanger 630 and heat rejector 640, and back to an inlet side 650 of the

pump 600 where oxygen is generated. The oxygen and hydrogen can recombine at a catalytic recombiner 655 located within a free volume at the inlet side 650 of the pump 600. In this way, the oxygen generated at the inlet side 650 will automatically recombine with the hydrogen introduced at charging, so that pressure buildup can be minimized.

In an alternative aspect of the present invention, as shown in Figure 4B, a method of cooling a heat-generating device using a cooling system is disclosed. In the step 450, a pump is used to cause a fluid to flow in a heat exchanger. In the step 460, an orifice coupled to the heat exchanger is adjusted in response to changes in pressure in the fluid to correspondingly adjust a boiling point temperature of the fluid. The method can further include the step of providing a heat rejector for rejecting heat from the system, the heat rejector being situated downstream of the heat exchanger, as shown in Figure 2.

The present invention discloses a system having at least one orifice, an inlet orifice 280 and an outlet orifice 285, through an inlet port and/or an outlet port of the heat exchanger. The orifices 280 and 285 are configured to direct fluid from a pump to microchannels within the heat exchanger. Orifices are employed for restricting flow rate, and the optimum size for restriction can be determined by employing an adjustable orifice. The orifices can be adjusted or designed such that, during boiling onset within the heat exchanger, there will be a targeted pressure in the heat exchanger during pump operation.

The present invention covers the use of pressure in the fluid to adjust a boiling point temperature of the fluid. However, in two-phase boiling flow, the optimal heat exchanger can use saturation pressure differentials and corresponding saturation temperature differentials. There is a direct relationship between saturation pressure and saturation temperature. When the pressure of a saturated liquid goes up, so does temperature; when pressure goes down, so does temperature. In alternative embodiment of the present invention, as shown in Figure 7A, a method of cooling a heat-generating device using a cooling system is disclosed. In the step 700, a pump is used to cause a fluid to flow in a heat exchanger. In the step 710, operating conditions of the pump are adjusted in response to at least one of: changes in pressure of the fluid; changes

in temperature of the fluid; changes in temperature of the heat-generating device; and changes in temperature of the heat exchanger. The method can further include the step of providing a heat rejector for rejecting heat from the system, the heat rejector being situated downstream of the heat exchanger, as shown in Figure 2.

In another embodiment of the present invention, as shown in Figure 7B, a method of cooling a heat-generating device using a cooling system is disclosed. In the step 750, a pump is used to cause a fluid to flow in a heat exchanger. In the step 760, an orifice is adjusted in response to at least one of changes in pressure of the fluid; changes in temperature of the fluid; changes in temperature of the heat-generating device; and changes in temperature of the heat exchanger. The method can further include the step of providing a heat rejector for rejecting heat from the system, the heat rejector being situated downstream of the heat exchanger, as shown in Figure 2.

In another embodiment of the present invention, as shown in Figure 7C, a method of cooling a heat-generating device using a cooling system is disclosed. In the step 780, a pump is used to cause a fluid to flow in a heat exchanger. In the step 790, a flexible volume reservoir or membrane that controllably expands or contracts is utilized to correspondingly adjust a pressure of the fluid in the heat exchanger.

The present invention further discloses a system having multiple pumps, and/or multiple heat exchangers, and/or multiple heat rejectors. For example, as shown in Figure 8, a cooling system 800 includes one pump 810, three heat exchangers 820, 830 and 840, and one heat rejector 850.

The present invention has been described in terms of specific embodiments incorporating details to facilitate the understanding of the principles of construction and operation of the invention. As such, references herein to specific embodiments and details thereof are not intended to limit the scope of the claims appended hereto. It will be apparent to those skilled in the art that modifications can be made to the embodiments chosen for illustration without departing from the spirit and scope of the invention.

Claims

We claim:

1. A method of cooling at least one heat-generating device using a cooling system, the method comprising the steps of:
using at least one pump to cause a fluid to flow in at least one heat exchanger; and adjusting a pressure of the fluid to correspondingly adjust a boiling point temperature of the fluid in the at least one heat exchanger.

2. The method of claim 1, wherein the step of adjusting a pressure of the fluid comprises adjusting operating conditions of the at least one pump in response to at least one of:
changes in pressure of the fluid;
changes in temperature of the fluid;
changes in temperature of the at least one heat-generating device; and
changes in temperature of the at least one heat exchanger.

3. The method of claim 1, wherein the step of adjusting a pressure of the fluid comprises adjusting an orifice coupled to the at least one heat exchanger in response to at least one of:
changes in pressure of the fluid;
changes in temperature of the fluid;
changes in temperature of the at least one heat-generating device; and
changes in temperature of the at least one heat exchanger.

4. The method of claim 1, wherein the method further comprises the step of: providing at least one heat rejector for rejecting heat from the system to ambient air, the at least one

heat rejector being situated downstream of the at least one heat exchanger.

5. The method of claim 4, wherein the method further comprises the step of providing a reservoir that accommodates a larger volume of a gas in the system generated during boiling.

6. The method of claim 5, wherein the reservoir reduces a change in pressure of the fluid that occurs during boiling.

7. The method of claim 5, wherein the reservoir is situated downstream of the at least one heat rejector..

8. The method of claim 5, wherein the reservoir is situated upstream of the at least one heat rejector.

9. The method of claim 5, wherein the reservoir having a volume region as great as the volume of vapor generated by the at least one heat exchanger during boiling of the fluid.

10. The method of claim 5, wherein the reservoir having an inlet coupled to a fluid outlet port of the at least one heat rejector via a first portion of a fluid transport line and an outlet coupled to a fluid inlet port of the at least one pump via a second portion of the fluid transport line.

11. The method of claim 5, wherein the reservoir is integrated with one of the at least one heat rejector and the at least one pump.

12. The method of claim 1, wherein the system is hermetically sealed.

13. The method of claim 12, wherein the hermetically sealed refers to a design in which the pressure under a given set of pump, ambient temperature, and heating conditions varies by less than 1 psi during a five year lifetime.

14. The method of claim 1, wherein the fluid is selected from a group consisting of water, acetonitrile, acetone, N-methylformamide, benzene, ethanol, methanol, and a combination thereof.

15. The method of claim 1, wherein the fluid comprises a halocarbon.

16. The method of claim 15, wherein the halocarbon is a methane series halocarbon selected from the group consisting of trichlorofluoromethane and trifluoromethane.

17. The method of claim 15, wherein the halocarbon is a ethane series halocarbon comprising pentafluoroethane (R-125).

18. The method of claim 1, wherein the fluid is a zeotropic blend comprising R-404A.

19. The method of claim 1, wherein the fluid is an azeotropic blend selected from the group consisting of R-500 and R-502.

20. The method of claim 1, wherein the fluid is inorganic.

21. The method of claim 20, wherein the inorganic is selected from the group consisting of ammonia and carbon dioxide.

22. The method of claim 1, wherein the fluid comprises a hydrocarbon.

23. The method of claim 22, wherein the hydrocarbon is selected from the group consisting of methane, ethane, propane, n-butane, 2-methylpropane, isobutane, ethene, ethylene, propene, propylene, and combinations thereof.

24. The method of claim 1, wherein the fluid is cryogenic.

25. The method of claim 24, wherein the cryogenic is selected from the group consisting of hydrogen, parahydrogen, helium, nitrogen, neon, air, oxygen, argon, and combinations thereof.

26. The method of claim 1, wherein the fluid is selected from the group consisting of water, acetonitrile, acetone, N-methylformamide, benzene, ethanol, methanol, halocarbons, zeotropic blends, azeotropic blends, inorganic fluids, hydrocarbons, cryogenic fluids, and mixtures thereof, the halocarbons being methane series halocarbons selected from the group consisting of trichlorofluoromethane, trifluoromethane and mixtures thereof, the zeotropic blends comprising R-404A, the azeotropic blends being selected from the group consisting of R-500, R-502 and mixtures thereof, the inorganic fluids being selected from the group of ammonia, carbon dioxide and mixtures thereof, the hydrocarbons being selected from the group consisting of methane, ethane, propane, n-butane, 2-methylpropane, isobutane, ethene, ethylene, propene, propylene and mixtures thereof, the cryogenic fluids being selected from the group consisting of hydrogen, parahydrogen, helium, nitrogen, neon, air, oxygen, argon and mixtures thereof.

27. The method of claim 1, wherein the method further comprises the step of: providing sensors to adjust the fluid flow from the at least one pump.

28. The method of claim 27, wherein the sensors being coupled to the at least one heat exchanger.

29. The method of claim 1, wherein the at least one pump is electro-osmotic.

30. The method of claim 1, further comprising the step of: delivering to a catalytic recombiner a gaseous stream containing hydrogen being discharged from a downstream side of the at least one pump together with an amount of oxygen generated from an upstream side of the at least one pump sufficient to convert the hydrogen and oxygen to water, the catalytic recombiner coupled to an inlet port of the at least one pump.

31. The method of claim 1, wherein the step of adjusting a pressure of the fluid comprises adjusting the pressure of the fluid during a charging and sealing of the system.

32. The method of claim 1, wherein the step of adjusting a pressure of the fluid comprises adjusting at least one of a composition and volume and combinations thereof of at least one of a gas and liquid and combinations thereof introduced during charging of the system.

Abstract of the Disclosure

A method of cooling at least one heat generating device using a cooling system is disclosed. The method comprises the steps of using at least one pump to cause a fluid to flow in at least one heat exchanger and adjusting a pressure of the fluid to correspondingly adjust a boiling point temperature of the fluid in the at least one heat exchanger. The method can also include the step of providing at least one heat rejector for rejecting heat from the system, the at least one heat rejector being situated downstream of the at least one heat exchanger. The step of adjusting a pressure of the fluid can comprise adjusting a pressure of the fluid during charging and sealing of the system. Further, the step of adjusting a pressure of the fluid can comprise adjusting a composition and volume of a gas and liquid introduced during charging of the system.

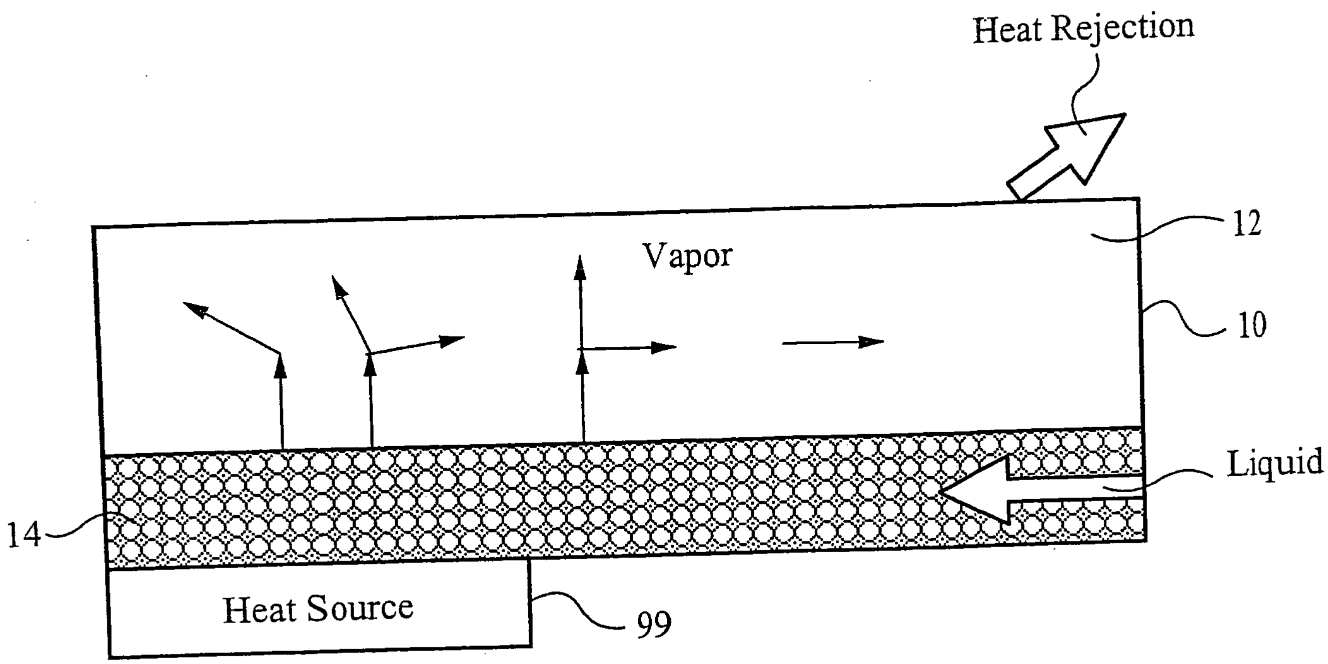

Fig. 1A (PRIOR ART)

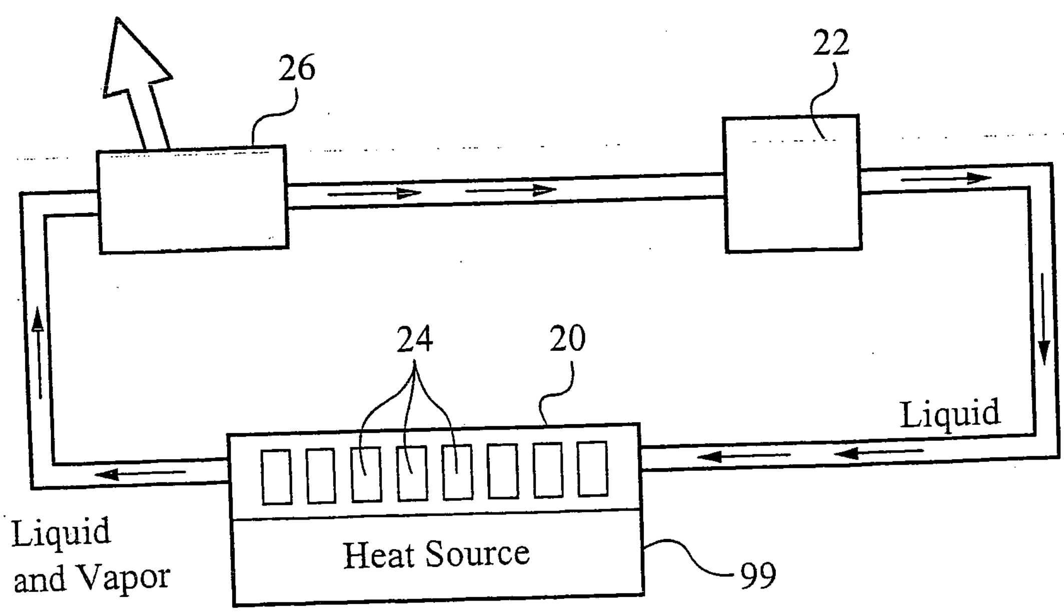

Fig. 1B (PRIOR ART)

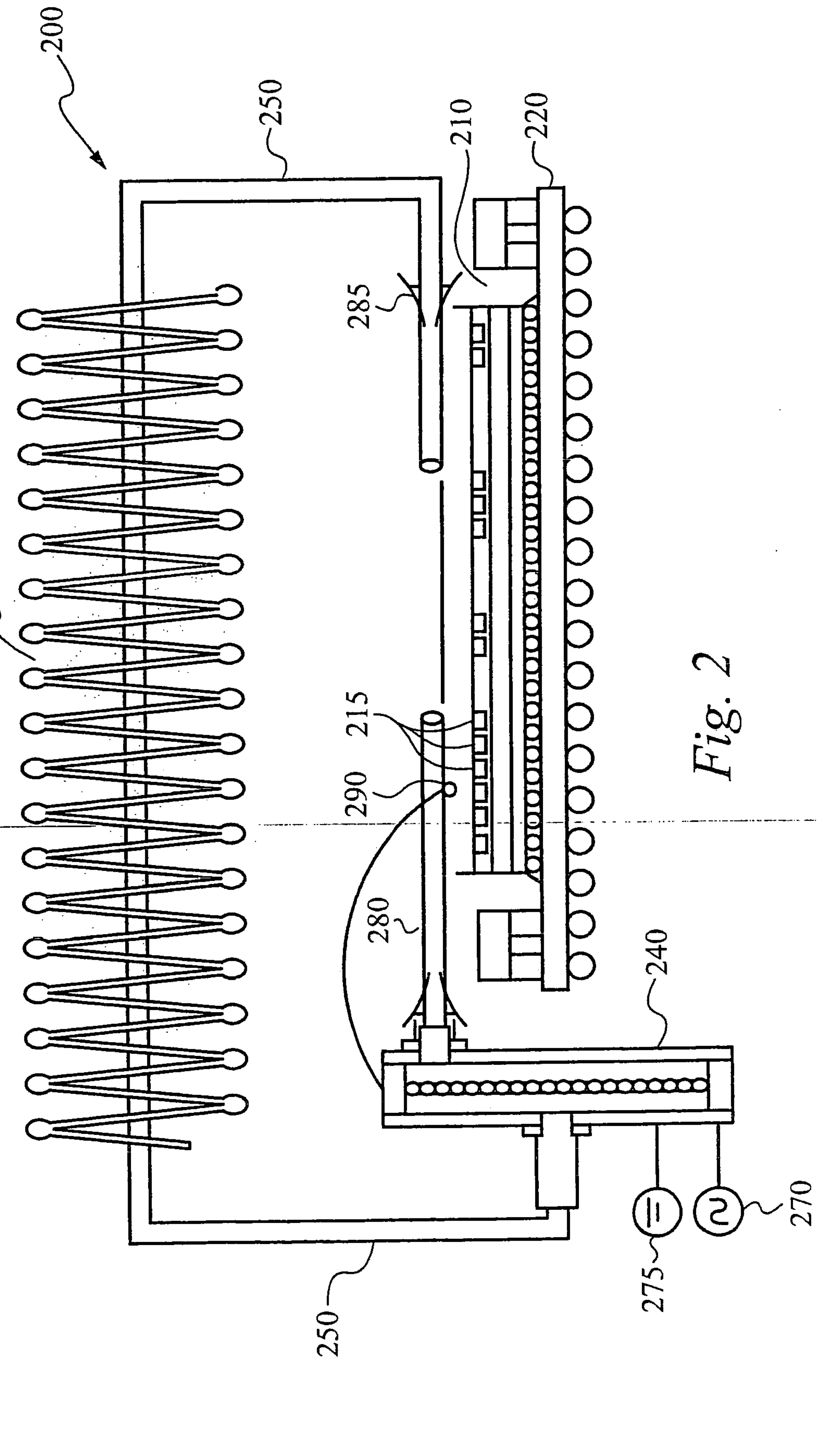

Fig. 2

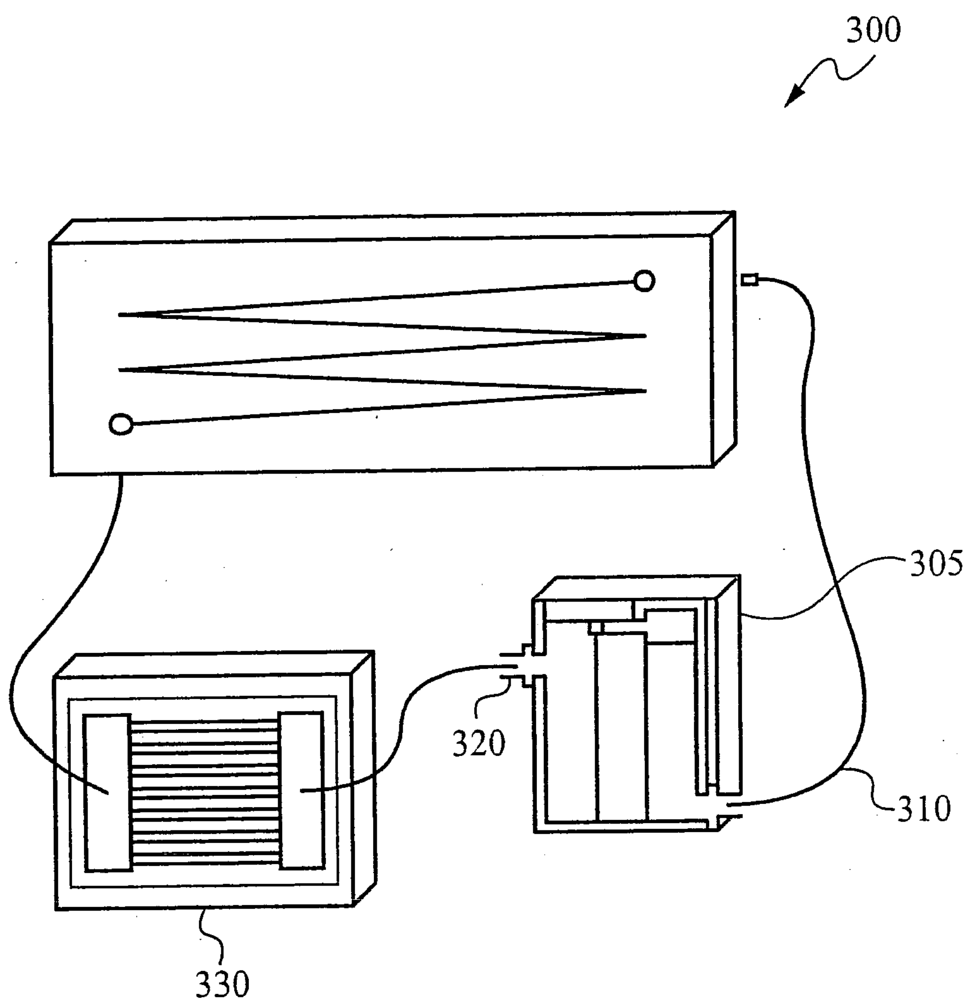

Fig. 3

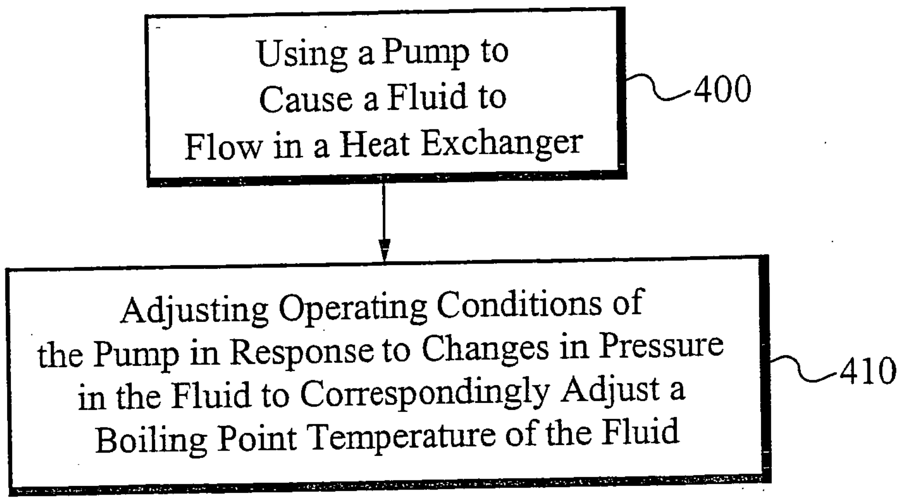
Using a Pump to
Cause a Fluid to
Flow in a Heat Exchanger
400
Adjusting Operating Conditions of
the Pump in Response to Changes in Pressure
in the Fluid to Correspondingly Adjust a
Boiling Point Temperature of the Fluid
410

Fig. 4A

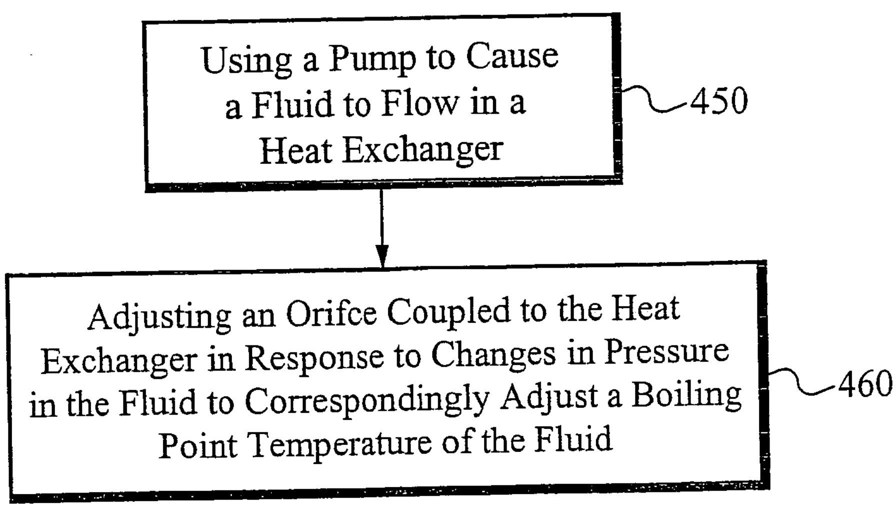
Using a Pump to Cause
a Fluid to Flow in a
Heat Exchanger
450
Adjusting an Orifce Coupled to the Heat
Exchanger in Response to Changes in Pressure
in the Fluid to Correspondingly Adjust a Boiling
Point Temperature of the Fluid
460

Fig. 4B

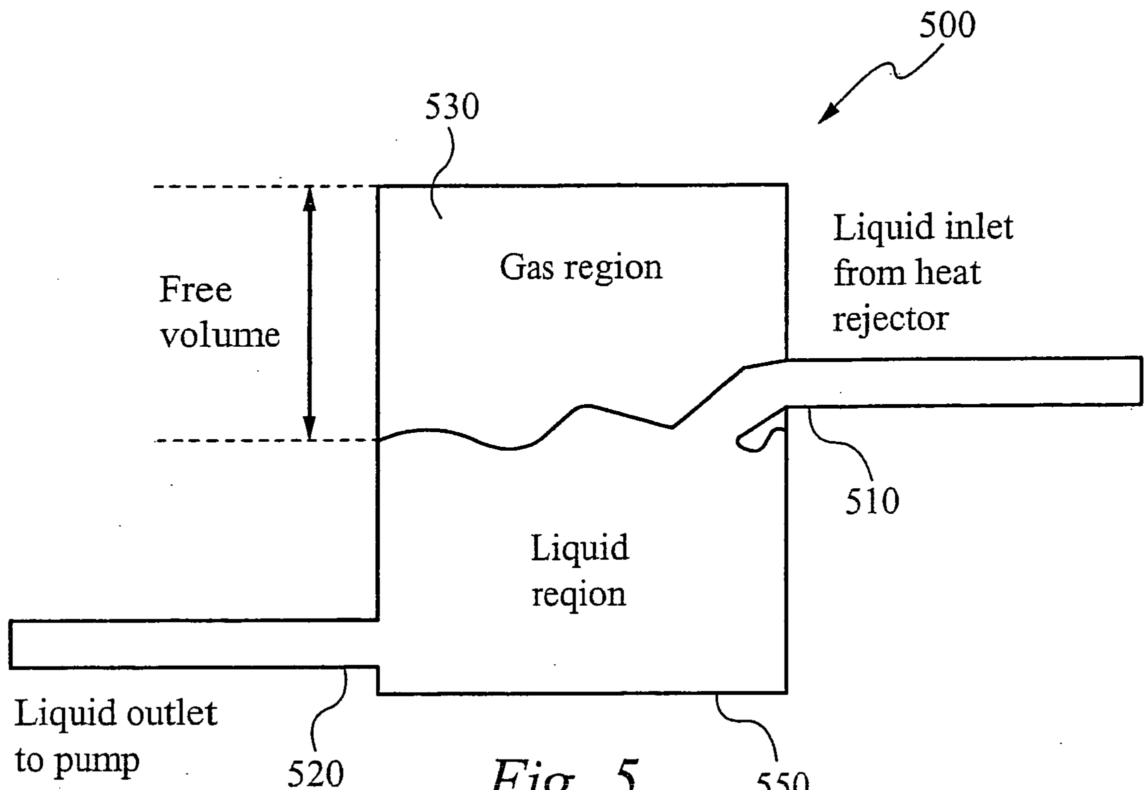
500
530
Gas region
Free
volume
Liquid inlet
from heat
rejector
510
Liquid
reqion
Liquid outlet
to pump
520
550

Fig. 5

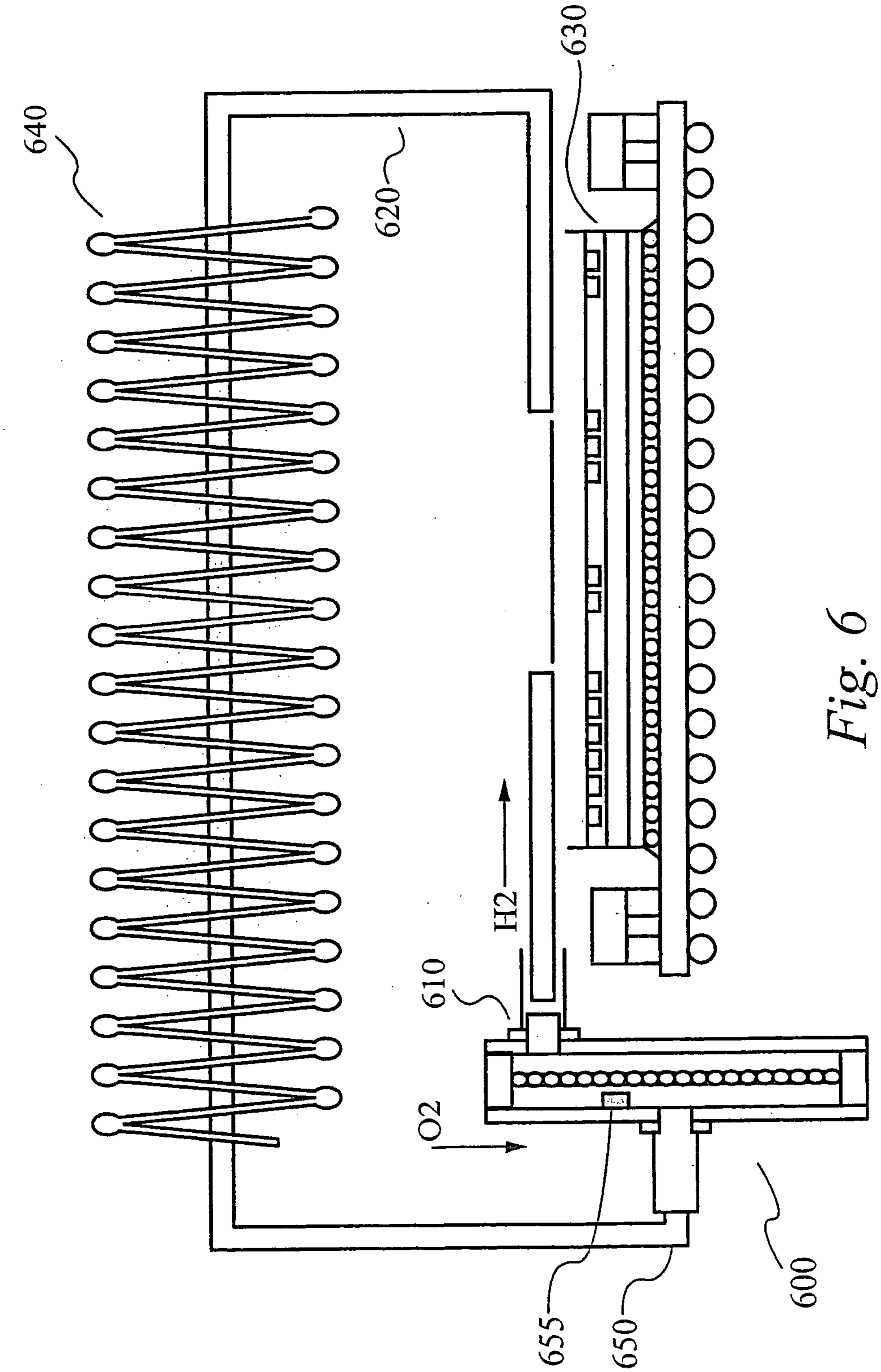

Fig. 6

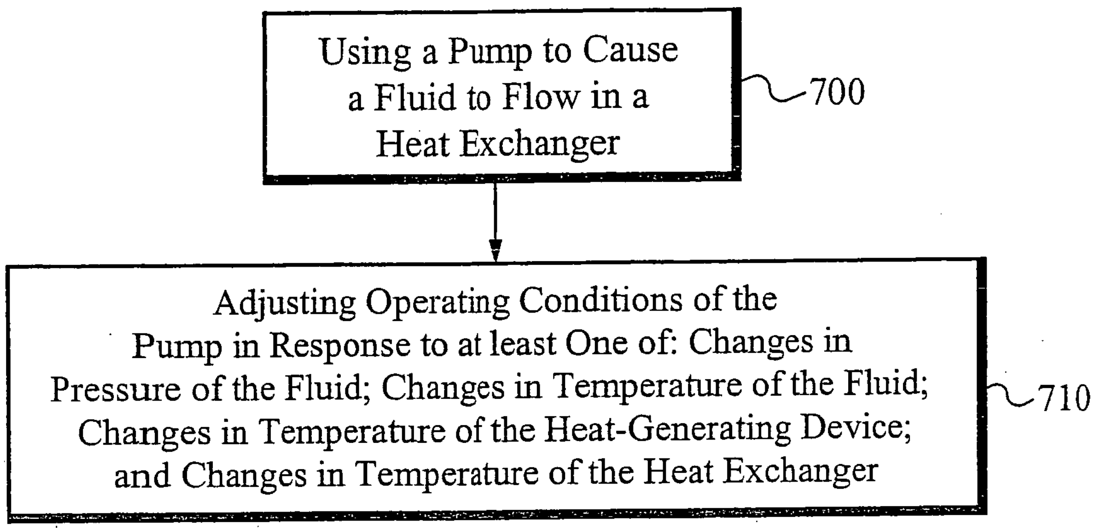
Using a Pump to Cause a Fluid to Flow in a Heat Exchanger
700
Adjusting Operating Conditions of the Pump in Response to at least One of: Changes in Pressure of the Fluid; Changes in Temperature of the Fluid; Changes in Temperature of the Heat-Generating Device; and Changes in Temperature of the Heat Exchanger
710

Fig. 7A

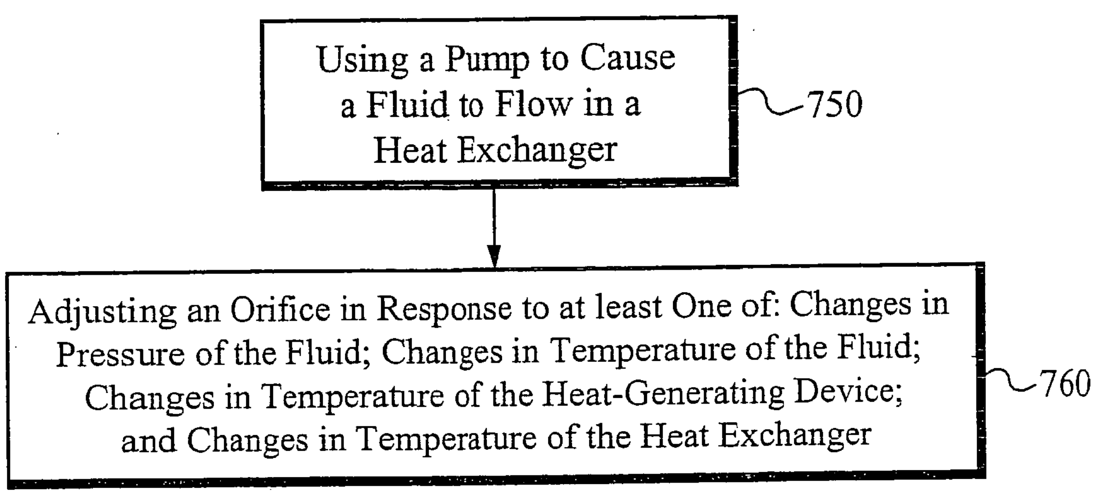
Using a Pump to Cause a Fluid to Flow in a Heat Exchanger
750
Adjusting an Orifice in Response to at least One of: Changes in Pressure of the Fluid; Changes in Temperature of the Fluid; Changes in Temperature of the Heat-Generating Device; and Changes in Temperature of the Heat Exchanger
760

Fig. 7B

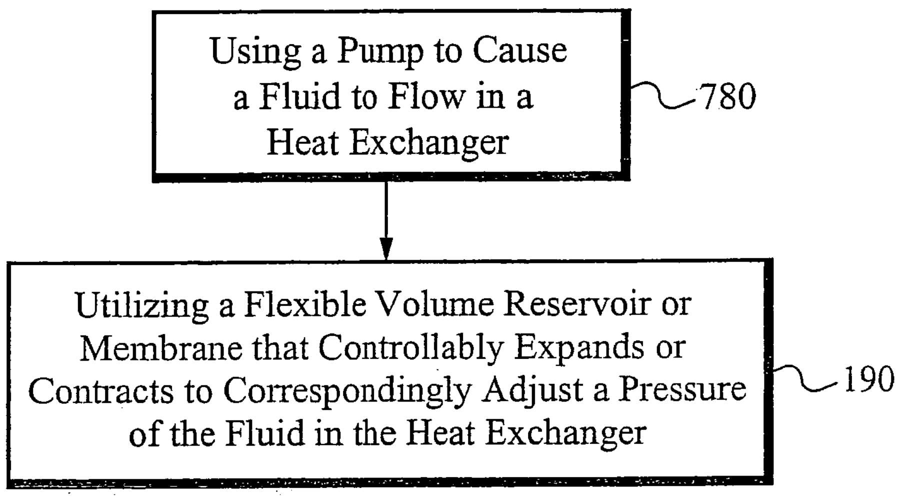
Using a Pump to Cause a Fluid to Flow in a Heat Exchanger
780
Utilizing a Flexible Volume Reservoir or Membrane that Controllably Expands or Contracts to Correspondingly Adjust a Pressure of the Fluid in the Heat Exchanger
190

Fig. 7C

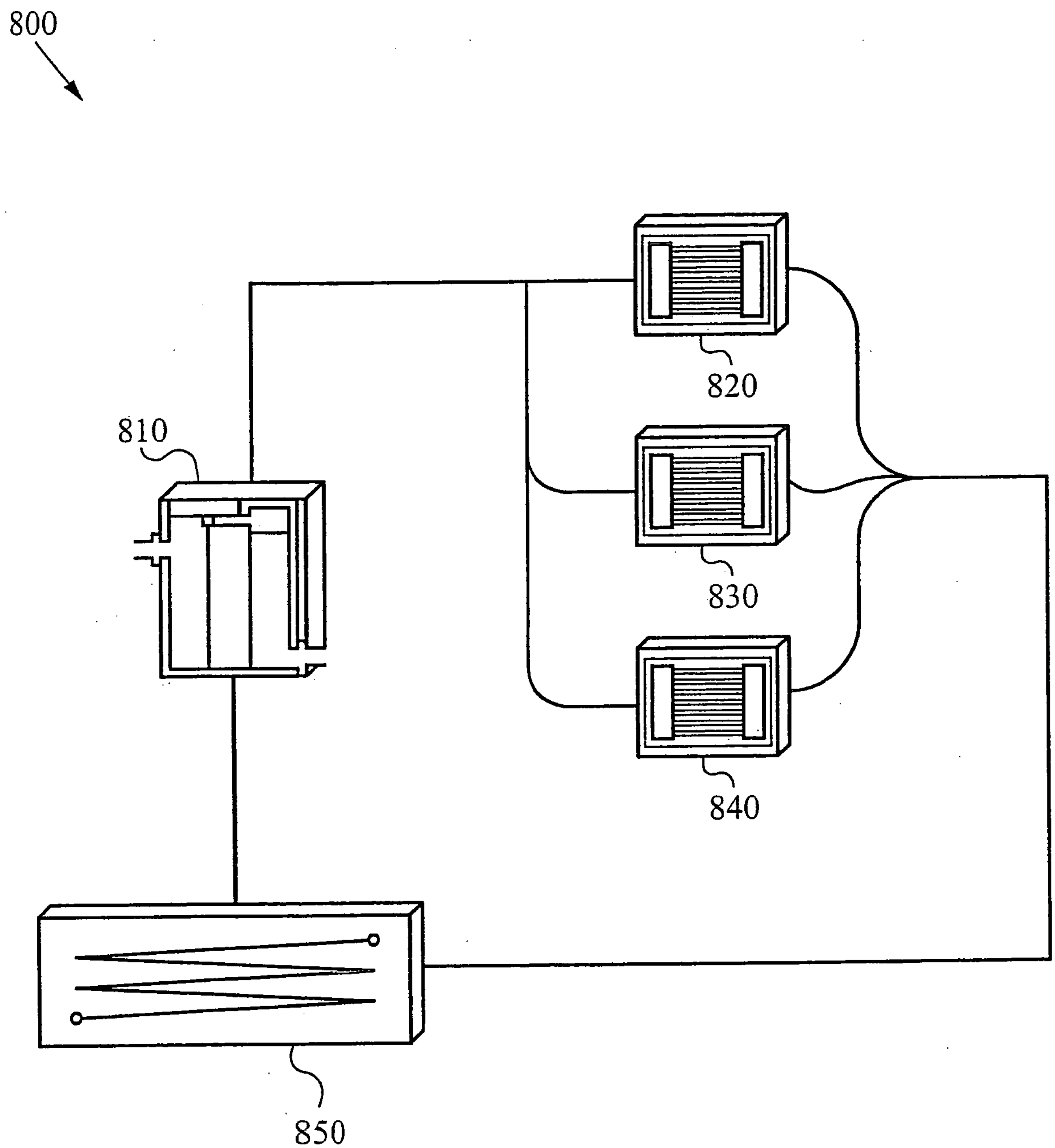

Fig. 8

MODELING OF TWO-PHASE MICROCHANNEL HEAT SINKS FOR VLSI CHIPS

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ABSTRACT

Microchannel heat sinks with forced convective boiling can satisfy the increasing heat removal requirements of VLSI chips. But little is known about two-phase boiling flow in channels with cross-sectional dimensions below 100 μm. This work develops and experimentally verifies microchannel simulations, which relate the temperature field to the applied power and flowrate. The simulations consider silicon conduction and assume an immediate transition to homogeneous misty flow, without the bubbly and plug-flow regimes in larger channels. Pressure drop and wall temperature predictions are consistent with data for a channel with cross-sectional dimensions of 50 μm × 70 μm. The simulations explore the performance of a novel heat sink system with an electrokinetic pump for the liquid phase, which provides 1 atm and 15 ml/min. A temperature rise below 40 K is predicted for a 200 W heat sink for a 25 mm × 25 mm chip.

INTRODUCTION

The increasing power densities of VLSI chips and novel chip integration technologies motivate the development of high-performance heat sinks [1]. According to the International Roadmap for Semiconductors, which provides conservative estimates, heat rates of Q = 160 W must be removed from chips with areas near A = 6 cm^2 with temperature rise less than ΔT = 40 K by the year 2005 [2]. This requires a thermal conductance of $G = Q/\Delta T$ = 4 W K^{-1}, which is impractical using macroscopic air-convection heat sinks. Thermal conductances exceeding 10 W K^{-1} will be needed for novel 3-dimensional circuits, which integrates MEMS, RF, CMOS, and optical devices [3] and dramatically increase the heat generated per unit surface area.

Tuckerman and Pease [4] showed that single-phase liquid convection in microchannels (channels with cross-sectional dimensions near 100 μm) provides G ~ 10 W K^{-1}. Two-phase boiling flow in microchannels promises comparable or better conductances at much lower flowrates with improved temperature uniformity. However, careful heat sink design and optimization are required to avoid dryout, which causes a large temperature rise in the chip. This is impossible at present because there are few data and no simulations available for two-phase microchannel convection.

There has been some experimental work on two-phase flow in channels with hydraulic diameters near or less than 100 μm [5-9]. The hydraulic diameter is $D = 4\,A_c\,/\,p$, where A_c and p are the area and perimeter, respectively, of the channel cross section [10]. Peng et al. [5,6] observed no bubbles in channels with hydraulic diameters between 150 and 650 μm, although the heat transfer rate suggested that phase change occured. This was called "fictitious" boiling and was attributed to the condition $D < D_{crit}$, where D_{crit} is diameter at which bubbles are stable considering surface forces and the pressure dependence of the saturation temperature. Stanley et al. [7] conducted two-phase flow experiments in rectangular channels with 56 μm < D < 256 μm. Inert gases were mixed with liquid water to eliminate evaporation and minimize variations in the mass flowrates of the liquid and gas phases. Pressure drop and conductance data were consistent with a model in which the liquid and gas flow velocities are identical, i.e., a *homogeneous* flow model. Jiang et al. [8] studied forced convective boiling in triangular silicon/glass channels with D = 40 and 80 μm and observed annular liquid-vapor flow. Zhang et al. [9] measured wall temperature distributions in single micromachined rectangular silicon/glass channels (30 μm < D < 60 μm) using integrated thermistors.

This work develops a practical modeling approach for two-phase microchannel heat sinks and compares predictions with data. The steady-state model accounts for conduction in the heat sink walls, convection within the channels, and the temperature and pressure dependence of fluid properties. Based on the past experimental work, the model assumes an immediate transition to homogeneous misty flow, without the bubbly and plug-flow regimes known to exist in larger channels. Predictions for pressure drop and channel wall temperature distribution are verified using the experimental data of Zhang et al. [9]. The calculations explore the performance of a microchannel heat sink based on an electrokinetic pump [11], shown in Figure 1. This system will address the challenges of VLSI integration by removing 200 W from a 2.5 cm × 2.5 cm chip using a compact pump for the liquid phase.

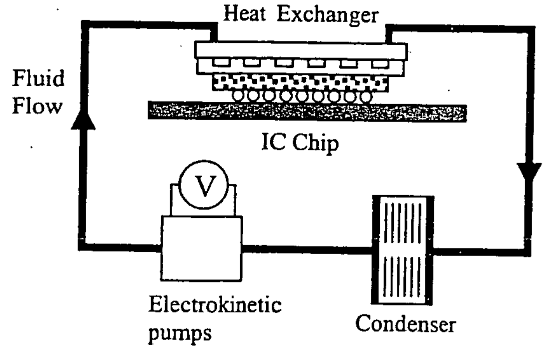

Figure 1. *Schematic of an electrokinetically-pumped microchannel cooler for VLSI circuits.*

THEORETICAL APPROACH

Figure 2 is a physical schematic of the flow regimes in microchannels, which are hypothesized from the microscopy of Peng et al. [5,6], Jiang et al. [8], and Zhang et al. [9] and the heat flux and pressure drop measurements of Stanley et al. [7]. In microchannel section A, the flow remains in the liquid phase until the local fluid temperature exceeds the saturation temperature at the local channel pressure. Within segment B, the flow is assumed

to erupt rapidly into two phases. Zhang et al. [9] reported that the flow in segment B is highly transient, with the vapor onset point oscillating in the longitudinal direction by a few channel diameters. Although Peng et al. [5,6] argued for the lack of the vapor phase in segment C, the vapor phase was observed by Jiang et al. [8] and Zhang et al. [9]. Among all of the studies there is a consensus that the bubbly flow and plug flow found in macroscopic channels is absent in microchannels. The present work hypothesizes that the flow in segment C consists of a homogeneous core, i.e., a mist of liquid droplets and vapor moving at the same velocity, surrounded by a very thin, slow-moving liquid film. Finally, for channels of sufficient length and for high rates of heat absorption, complete dryout occurs with the fluid entirely in the vapor phase in Segment D.

Critical to the present analysis is the homogeneous flow assumption for the two-phase segments B & C, which assigns identical velocities for the liquid and vapor phases and dramatically simplifies the treatment. The homogeneous assumption neglects the complex transient hydrodynamics in segment B, and neglects the slower velocity of the very thin liquid film in segment C. However, the homogeneous assumption is supported by the heat flux and pressure drop measurements of Stanley et al. [7]. Furthermore, the differences in liquid and vapor velocities are expected to diminish in small channels, in which the small droplet size increases the shear force per unit volume.

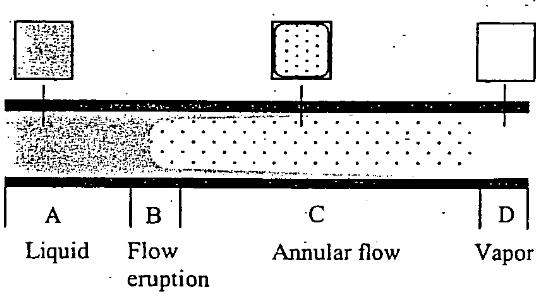

Figure 2. Schematic of flow regimes in channels with hydraulic diameters near and below 100 μm. The regimes are hypothesized based on published experimental work [5-9].

Figure 3 illustrates the heat sink geometry. The heat flux q'' is assumed uniform, such that symmetry allows the analysis of only one channel. This does not account for flow mixing at channel inlet and outlet reservoirs. The average local temperatures of the solid wall, the fluid, and the surroundings are T_w, T_f, and T_∞, respectively, and i_f is the fluid enthalpy per unit mass. The governing energy equations are

SOLID:

$$\frac{d}{dz}\left(k_w A_w \frac{dT_w}{dz}\right) - \eta h_{conv} p(T_w - T_f) - \frac{w(T_w - T_\infty)}{R_{env}} + q''w = 0 \quad (1)$$

FLUID:

$$\dot{m}\frac{di_f}{dz} - \eta h_{conv} p(T_w - T_f) = 0 \quad (2)$$

where z is the coordinate along the channels, A_w is the solid cross-sectional area, p is the perimeter of the microchannel cross section, and w is the pitch of the microchannels. The thermal conductivity of solid is k_w, $\dot{m}$ is the mass flow rate, and h_{conv} is the convection coefficient for heat transfer between the solid wall and the fluid. Eq. 1 accounts for heat conduction along the heat sink in the first term and the second term quantifies the heat transfer rate from solid to liquid. The third term in Eq. 1 accounts for heat transfer from the channel directly to the environment using the resistance R_{env}, and depends on the experimental configuration. The fin effectiveness η is between zero and unity and accounts for the temperature variation within the channel walls at a given position z [10]. The energy balance equation for fluid flow relates the change of the average enthalpy density of the fluid against the heat transfer rate into the fluid from the walls assuming homogeneous flow conditions.

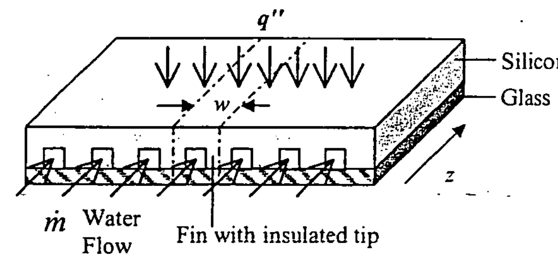

Figure 3. Schematic of microchannel heat sink for model development.

The pressure gradient is calculated using a momentum balance along the channel, which for the case of homogeneous flow can be simplified to [12]

$$-\left(\frac{dP}{dz}\right) = -\frac{P}{A_c}\left(\frac{dA_c}{dz}\right) + \frac{fm''^2}{2\rho D} + \left(\frac{1}{A_c}\right)\frac{d}{dz}\left(\frac{m''^2 A_c}{\rho}\right) \quad (3)$$

The pressure is P, m'' is the mass flux, ρ is the density of a unit volume of the liquid-vapor mixture. The density is expressed in terms of the fluid quality x, which is the mass fraction of the vapor phase, using

$$\frac{1}{\rho} = \frac{(1-x)}{\rho_l} + \frac{x}{\rho_v} \quad (4)$$

where ρ_l and ρ_v are the densities of the liquid and vapor phases, respectively. The channel cross sectional area is A_c and the hydraulic diameter is D. The unitless friction factor f fixes the wall shear stress through $f = 8\tau / (\rho U^2)$, where τ is the average fluid shear stress per unit wall surface area and U is the homogeneous two-phase velocity.

Eqs. 1-3 are differential statements of energy and momentum conservation for the fluid and walls, and are exact given the homogeneous flow assumption. The analysis becomes more approximate, however, as we calculate the friction factors and heat transfer coefficients needed in these equations. Stanley et al. [7] proposed the following globally averaged friction factor for two-phase microchannels

$$f = \frac{97}{Re} \quad (Re < 3000) \quad (5)$$

where $Re = U\,D\,/\,\nu$, where ν is the mass averaged kinematic viscosity of the two phases. This friction coefficient is about 70

percent larger than that for single-phase laminar flow in a channels because of the extra shear stress induced by mixing. Although Eq. 5 was developed for the average shear stress along a channel, it is applied locally in the present analysis.

The heat transfer coefficient, h_{conv}, for purely liquid-phase flow before boiling is $h_l = C\, k_f / D$, where k_f is the fluid thermal conductivity and C is a constant of order unity taken from exact solutions for a rectangular channel of a given aspect ratio [10]. The heat transfer coefficient for two-phase flow is calculated using Kandlikar's correlation [12] given by

$$h_{conv} = h_l \left[C_1 Co^{C_2} (25 Fr_{le})^{C_5} + C_3 Bo^{C_4} F_k \right] \quad (6)$$

where h_l is the heat transfer coefficient for the liquid phase flowing alone. The factor F_k is a fluid dependent parameter whose value for water is unity. The first term in the parenthesis accounts for the forced-convective effect on heat transfer and the second term accounts for the effect of nucleate boiling in regions with low quality. The constants C_1 to C_5 are determined from the value of Co. The dimensionless parameters are

$$Co = \left(\frac{1-x}{x}\right)^{0.8} \left(\frac{\rho_v}{\rho_l}\right)^{0.5}, \quad (7)$$

$$Bo = \frac{q''}{m'' i_{lv}}, \quad (8)$$

$$Fr_{le} = \frac{m''^2}{\rho_l^2 g D} \quad (9)$$

where ρ_v and ρ_l represent vapor and liquid densities in the saturation state. The heat of vaporization per unit mass is i_{lv} and g is the acceleration due to gravity. Eqs. 6-9 were developed for macroscopic channels, in which bubbly and annular flow regimes are important. The heat transfer coefficients in microchannels may be substantially different, particularly in Section C. Water properties are incorporated using thermodynamic property correlations [13] accounting for their dependence on temperature and pressure.

The calculation solves energy equations 1 and 2 for the solid wall and the convecting fluid, with boundary conditions dictated by the heat losses to the packaging of the microchannel, using the finite volume method [14]. Since this modeling includes a high degree of nonlinearity due to the temperature-dependent properties of water, the under-relaxation method is employed for each iteration.

COMPARISON WITH EXPERIMENTAL DATA

Zhang et al. [9] measured wall temperature distributions and the total pressure drop along a channel with dimensions of 50 μm (width) × 70 μm (depth) × 20 mm (length). A doped silicon thermistor was fabricated on the opposite side of the channel using implantation into an SOI substrate. Contacts along the length of the resistor allow local voltage electrical resistance measurements, from which temperature distribution data were obtained. The inlet and outlet heat losses, shown in Fig. 4, are expressed as boundary conditions for Eqs. 1 and 2 in terms of thermal resistances. In the calculations, 200 grid volume elements are used for the microchannel and 100 grid points in total for the inlet and exit regions.

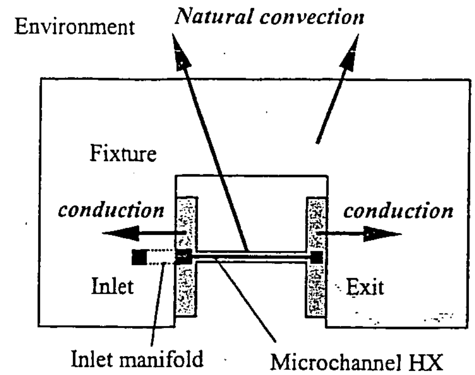

Figure 4. Top view schematic of the experimental apparatus and heat loss paths in the experiment of Zhang et al. [9].

Figure 5 shows reasonable agreement between predictions and data for the pressure drop as a function of applied heating power. The pressure drop decreases as the applied power increases in liquid phase since the viscosity of water decreases with temperature. Starting with the onset of two-phase flow, the pressure drop increases rapidly with increasing heating rate due to the acceleration of the liquid into the vapor phase. The reasonable agreement for purely liquid flow confirms that the macroscopic theory for momentum and heat transfer is valid for single-phase liquid flow in channels. The model underpredicts the data for powers less than about 0.75 W. This results from an overprediction of the fluid temperature rise, and therefore an underprediction of the liquid viscosity, which will be discussed in the next paragraph. The pressure drop for two-phase flow is dominated by the contribution due to the fluid acceleration, i.e., the third term on the right side of Eq. 3. Therefore, the agreement of predictions and data for the two-phase flow regime provides a reasonable confirmation of the predictions of the fluid exit quality x as a function of the applied heating power. This agreement also provides indirect support for the homogenous flow assumption, which strongly influences the pressure drop through the imposed acceleration of the liquid phase in the two-phase regime. The agreement of the pressure drop data provides little information about the accuracy of the friction coefficient provided in Eq. 5 because the pressure drop due to shear is small in the two-phase regime.

Figure 6 compares predictions and data for the wall temperature distribution along the channel for values of heating above and below the onset of boiling. While there is qualitative agreement in the temperature magnitudes, there are deviations particularly in the middle of the channel for the case of 0.61 W and for the entry region for the power of 2.12 W. For the case of 0.61 W, the difference probably results from an error in the term R_{env} in Eq. 1. This resistance has a much smaller impact on the temperature distribution for higher heating powers, for which a larger fraction of the heat is absorbed by the boiling fluid. The error in the entry region for 2.12 W is caused by liquid pre-heating in the tube attached to the fixture. The experiments were performed at sequentially higher powers, which caused the fixture to increase in temperature and resulted in more substantial fluid preheating for the case of 2.12 W compared to 0.61 W. Despite the discrepancies between data and predictions, the calculations are reasonably effective at predicting the temperature magnitude and the onset of boiling, as confirmed by the pressure predictions and

data shown in Figure 5. The simulation shows that the fluid absorbs about 75 percent of the applied heat and the remaining heat is transferred to the test structure fixture, which agrees with the estimates of Zhang et al. [9] based on the exit temperature of the fluid. The qualitative agreement provides support for the convection correlation (Eq. 6) used for two-phase flow, which has not previously been applied to channels with hydraulic diameter below 500 μm.

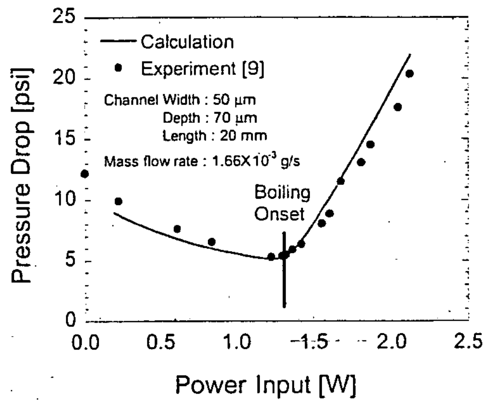

Figure 5. Predictions and data [9] for the pressure drop along a single channel.

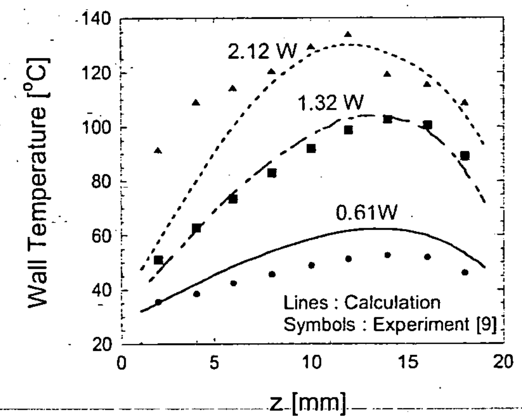

Figure 6. Predictions and data [9] for the wall temperature distribution along a single channel for varying heating powers.

HEAT SINK DESIGN

The model allows thermal design and optimization calculations for a VLSI heat sink with multiple channels. This section addresses the specific problem of a heat sink removing 200 W from a chip with dimensions 25 mm × 25 mm. These constraints are dictated by a novel cooling system based on a polymer-structure electrokinetic pump [11], which will deliver 15 ml/min of liquid water with a maximum pressure drop near 2 atm. Figure 7 shows the basic geometry of the silicon heat sink. The channel wall thickness is fixed at 100 μm and variations of the width and depth are explored in the range between 50 and 250 μm. The outlet pressure is fixed at P = 1 atm and the inlet temperature T_{in} is fixed at 333 K. The heat sink performance is quantified using average and minimum thermal conductances,

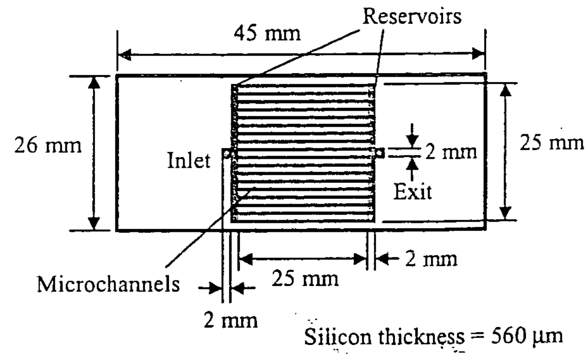

Figure 7. Schematic of a 200 W microchannel heat sink.

$$G_{ave} = \frac{Q}{T_{w,avg} - T_{in}} \quad (10) \qquad \text{and} \qquad G_{min} = \frac{Q}{T_{w,max} - T_{in}}. \quad (11)$$

The applied power is Q, and $T_{w,avg}$ and $T_{w,max}$ are the average and maximum wall temperatures, respectively. The average conductance is a figure of merit for the overall performance of the heat sink, while the minimum conductance is used to calculate the peak temperature.

Figure 8 illustrates the dependence of the conductances and the pressure drop on the channel dimensions. For a given channel width, the number of channels is fixed by the wall thickness and the total heat sink width of 25 mm. The pressure drop decreases with increasing channel width and depth because of the increasing total flow area, according to Eq. 3, because the mass flux and therefore the velocity of the homogeneous two-phase flow are reduced. Although narrower channels increase the local heat transfer coefficient in both the liquid and vapor phases, the extreme pressure drops along these channels cause a substantial increase in the saturation temperature at the onset of two-phase flow. The fluid temperature in the two-phase regime is fixed at the local saturation temperature, which decreases with decreasing pressure. The conductance prediction is most complicated at the onset of two-phase flow, because at this point the heat transfer coefficient increases dramatically from the single-phase value, h_l, to the value for two-phase flow in Eq. 6. The relative increase in h is smaller for larger channel diameters. This results in a small decrease in the conductance prediction with channel width, which competes against the influence of the saturation temperature. Based on these calculations and constraints, the channels should be made with the greatest possible depth and with width near 150 μm.

Figure 9 plots the predicted values of the critical heat flow rate Q_{CHF} and the required hydraulic work at this condition. The required pump power is governed by the hydraulic work and by the efficiency of the pump. The critical heat flow induces dryout in Section D in Figure 2 such that the fluid quality is 1, i.e., the flow is fully vapor phase. The critical heat flow rate Q_{CHF} increases linearly with flowrate because it is the product of the mass flowrate and the heat of vaporization of water. The hydraulic work is the product of pressure drop and the liquid volumetric flowrate at the inlet temperature. Since the pressure drop is proportional to the square of mass flow rate as shown in Eq. 3, the pump power increases with the square of the mass flowrate. After dryout, the heat transfer coefficient decreases rapidly and the wall temperature increases abruptly. Because the reduction in heat transfer coefficient associated with dryout might occur even when the

quality is below the unity, Figure 9 provides an upper bound for the acceptable heat flow at a given mass flowrate.

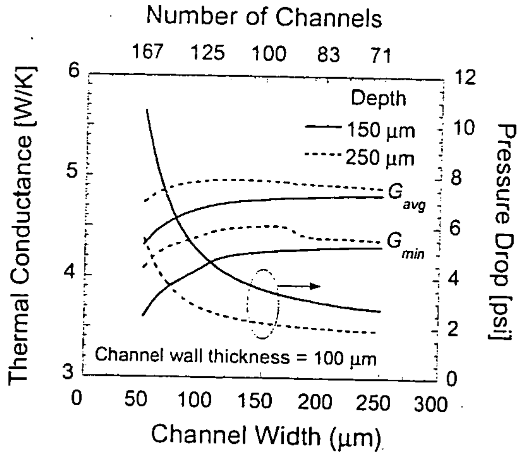

Figure 8. Dependence of thermal conductance of the 200 W microchannel heat sink on the channel width.

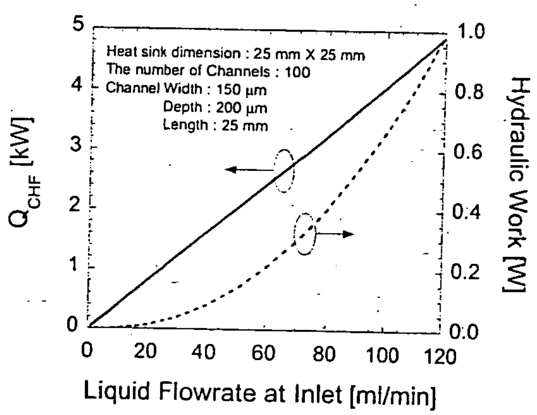

Figure 9. Maximum heat removal capacity and required hydraulic work of a 200W microchannel heat sink.

CONCLUSIONS

The calculations show that a temperature rise of 40 K is possible for a 200 W heat sink with dimensions 25 mm × 25 mm and for a pump providing less than 2.8 psi of pressure and 15 ml/min of liquid water. While the optimal channel cross-sectional dimensions depend strongly on the flowrate and pressure drop available from the pump, this work shows that the channel height should be as deep as possible given manufacturing constraints, while the channel width has a relatively small influence on the heat transfer rate.

Future fundamental work needs to more carefully resolve the two-phase flow regimes outlined in Figure 2 through microscopy and localized pressure distribution measurements. This will be critical for interpreting and modeling the transient nature of two phase flow and the onset of dry-out. Future optimization work needs to study the impact of dielectric fluids.

The one-dimensional microchannel simulations developed here are simple enough for heat sink design calculations using PC, yet capture enough of the physics to yield reasonable agreement with experimental data. A three-dimensional treatment of the problem would require far greater computational resources, as well as detailed knowledge about two-phase flow that is currently unavailable. More detailed simulations involving, for example, lattice dynamics methods, may eventually resolve enough information about the flow regimes to be useful for design [15].

ACKNOWLEDGMENTS

The research is sponsored by the DARPA HERETIC Program through contract F33615-99-C-1442. Lian Zhang acknowledges support of a Stanford Graduate Fellowship, and Kenneth E. Goodson and Thomas W. Kenny appreciate support from NSF through the CAREER Program.

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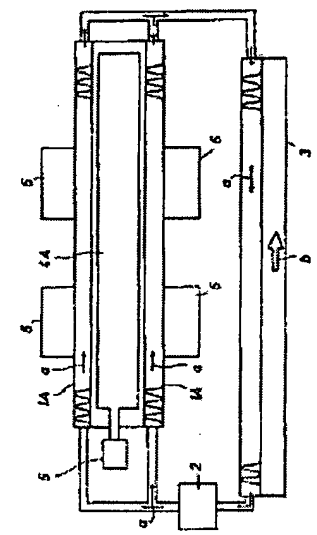
POD COOLING DEVICE

Patent number: JP1256775
Publication date: 1989-10-13
Inventor: YAMAGUCHI TOSHIAKI
Applicant: MITSUBISHI ELECTRIC CORP
Classification:
- international: F25D9/00; B64D13/08
- european:
Application number: JP19880082669 19880404
Priority number(s):

Abstract of **JP1256775**

PURPOSE:To simplify the structure of a cooling device in order to make the cooling unit compact by applying two independent cooling units, liquid and evaporation cooling units, and by cooling cold plates directly in case of evaporation cooling.

CONSTITUTION:In case of liquid cooling, a circulating refrigerant 'a' is sent to cold plates 1A by a circulating pump 2, and heat-exchange takes place while the refrigerant passes through the cold plates to cool electronic devices 6. The warmed circulating refrigerant 'a' is cooled by heat-exchanging with ram air 'b' in an exterior plate heat exchanger 3, and then returned to the cold plates 1A. When the performance of the exterior plate heat exchanger 3 drops and the temperature of the electronic apparatus 6 rises over a set value, the circulating pump 2 stops and the cold plates 1A are directly cooled by the latent heat of evaporation of the refrigerant in a heat exchanger 4 for evaporation cooling. The evaporated refrigerant is discharged from a relief valve 5. To adopt the relief valve 5 allows free adjustment of the boiling point of the refrigerant for evaporation cooling by changing the pressure of the refrigerant.



⑲日本国特許庁（JP）　⑪特許出願公開

⑫公開特許公報（A）　平1－256775

⑤Int. Cl.⁴　識別記号　庁内整理番号　㊸公開　平成1年(1989)10月13日

F 25 D 9/00　7001－3L
B 64 D 13/08　7615－3D

審査請求　未請求　請求項の数 1 （全4頁）

㊹発明の名称　ポッド冷却装置

㉑特　願　昭63－82669
㉒出　願　昭63(1988)4月4日

⑫発明者　山口　俊明　兵庫県尼崎市塚口本町8丁目1番1号　三菱電機株式会社通信機製作所内
⑪出願人　三菱電機株式会社　東京都千代田区丸の内2丁目2番3号
⑭代理人　弁理士　大岩　増雄　外2名

明　細　書

1. 発明の名称

ポッド冷却装置

2. 特許請求の範囲

(1) 電子機器を冷却するコールドプレート、このコールドプレートを冷却する循環冷媒を送る循環ポンプ、ラムエアにより前記循環冷媒を冷却する外板熱交換器、前記循環冷媒による液冷によつて前記コールドプレートを冷却できなくなつた時に沸騰冷却方式により前記コールドプレートを冷却するための沸騰冷却用熱交換器、および気化した沸騰冷却用冷媒を排気、圧力調整をするレリーフバルブを備えたことを特徴とするポッド冷却装置。

3. 発明の詳細な説明

〔産業上の利用分野〕

この発明は、航空機の胴下あるいは翼下に搭載されるポッド内の電子機器の温度をコントロールするための冷却装置に関するものである。

〔従来の技術〕

第5図、第6図は従来のポッド冷却装置を示す断面図であり、図において(1)は電子機器(6)を搭載するコールドプレート、(2)は冷媒(a)を循環させる循環ポンプ、(3)は循環冷媒(a)の温度を下げるための外板熱交換器、(4)は沸騰冷却用熱交換器、(5)は気化した冷媒を排気するレリーフバルブ、(7)は冷媒(a)を外板熱交換器(3)あるいは沸騰冷却用熱交換器(4)に送るためのバイパスバルブ、(8)はバイパスバルブ(7)の中にある冷媒(a)の温度を検出する温度センサ、(9)は沸騰冷却で使用する水の入つた水タンク、（10）はチエツクバルブ、（11）はポッド胴体である。

次に動作について説明する。外板熱交換器(3)はラムエア(b)を使用して熱交換を行なうため、その能力は航空機の飛行条件により異なつてくる。まず、温度センサ(8)により循環冷媒(a)の温度を検出する。循環冷媒(a)の温度が低い時には外板熱交換器(3)による液冷方式により行ない、そして冷媒(a)の温度が高くなると冷却能力の高い沸騰冷却方式により行なう。液冷方式では、

第5図中実線矢印で示すように冷媒(a)は循環ポンプ(2)により送られ、電子機器(6)が搭載されているコールドプレート(1)を通り熱をうばう。温度が上昇した冷媒(a)は外板熱交換器(3)に送られてラムエア(b)により冷却され、再びコールドプレート(1)に送られる。外板熱交換器(3)の能力が落ちて、冷媒(a)の温度が上昇してくると、バイパスバルブ(7)から冷媒(a)は第5図中点線矢印で示すように沸騰冷却用熱交換器(4)に送られる。ここで、冷媒(a)は水タンク(9)内の水を蒸発させて熱交換を行ない、冷却されてチエツクバルブ(10)を通り、再びコールドプレート(1)に送られる。蒸発した水はレリーフバルブ(5)を通り排気される。したがつて、冷却時間は水の量に依存する。

〔発明が解決しようとする課題〕

従来のポッド冷却装置は以上のように構成されているので、冷媒(a)の温度により冷却方法を換えるためのバイパスバルブ(7)が必要で、装置が大きく複雑になるなどの問題点があつた。

この発明は上記のような問題点を解消するためになされたもので、軽量コンパクトなポッド冷却装置を得ることを目的とする。

〔課題を解決するための手段〕

この発明に係るポッド冷却装置は、液冷と沸騰冷却のそれぞれの冷却装置を独立にし、沸騰冷却では循環冷媒を冷却し、コールドプレートを冷却するのではなく、直接コールドプレートを冷却するものである。

〔作用〕

この発明におけるポッド冷却装置は、液冷装置と沸騰冷却装置を独立にすることにより、バイパスバルブが不要となり、沸騰冷却時に循環ポンプを作動する必要がなくなり、ポンプ発熱を零にする。

〔発明の実施例〕

以下、この発明の一実施例を第1図、第2図について説明する。第1図は縦断側面図、第2図は縦断正面図であり、前記従来装置と同一または相当部分には同一符号を付して説明を省略する。図において、(1A)は電子機器(6)を搭載するコールドプレートで、上下二列状に並設されている。(4A)はコールドプレート(1A),(1A)間に配置した沸騰冷却用熱交換器である。

次に上記実施例の動作を説明する。液冷方式では、循環ポンプ(2)から送り出された循環冷媒(a)はコールドプレート(1A),(1A)を通る際、熱交換を行ない電子機器(6)を冷却する。温度が上昇した循環冷媒(a)は外板熱交換器(3)でラムエア(b)と熱交換を行ない冷却され、再びコールドプレート(1A),(1A)に送られる。外板熱交換器(3)の能力が落ちて電子機器(6)の温度が上昇し、ある設定温度を越えると、循環ポンプ(2)が停止し、沸騰冷却用熱交換器(4A)内の冷媒が沸騰するその気化熱によりコールドプレート(1A),(1A)を直接冷却する。沸騰した冷媒はレリーフバルブ(5)から排気される。したがつて、冷却時間は沸騰冷却用熱交換器(4A)内の冷媒の量に依存する。

このようにレリーフバルブ(5)を設けておくと、このレリーフバルブ(5)を使用することにより沸騰冷却用冷媒の圧力を変え冷媒の沸点を自由に調整できるものである。

上記実施例ではコールドプレート(1A),(1A)間に沸騰冷却用熱交換器(4A)がはさまれたものを示したが、第3図に示すように一列状のコールドプレート(1B)に液冷方式による循環冷媒が通る流路(1a)と沸騰冷却用熱交換器(4B)とを設けてもよい。また、第4図に示すように第1図、第2図のコールドプレート(1A),(1A)内に循環冷媒が通る流路(1a)を設けず、沸騰冷却用熱交換器(4C)内に液冷用熱交換器(12)を通すようにしてもよい。

さらに、特別に沸騰冷却用熱交換器を設けず、液冷方式で使用するコールドプレートを冷却する循環冷媒が通る流路を沸騰冷却時にも使用し、循環冷媒を沸騰させてもよい。

〔発明の効果〕

以上のように、この発明によれば沸騰冷却の時は直接コールドプレートを冷却するように構成したので、装置が小型化でき、構造が簡単なものが得られる効果がある。

4.図面の簡単な説明

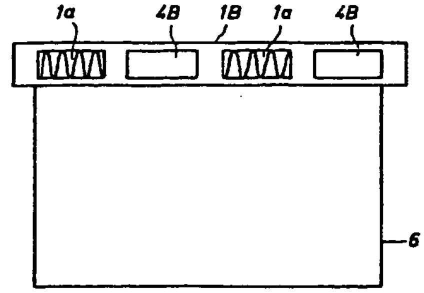
第1図はこの発明の一実施例によるポッド冷却装置を示す縦断側面図、第2図はその縦断正面図、第3図および第4図はこの発明のそれぞれ異なる実施例を示す縦断正面図、第5図は従来のポッド冷却装置を示す縦断側面図、第6図はその縦断正面図である。

図において、(1A)はコールドプレート、(2)は循環ポンプ、(3)は外板熱交換器、(4A)は沸騰冷却用熱交換器、(5)はレリーフバルブ、(6)は電子機器である。

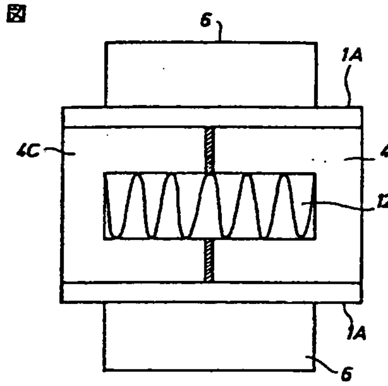
なお、各図中同一符号は同一または相当部分を示す。

代理人　弁理士　大　岩　増　雄

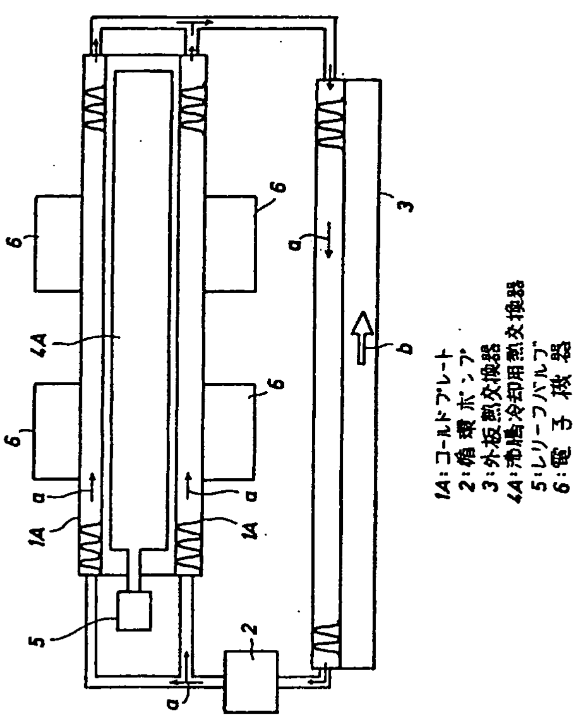
第3図



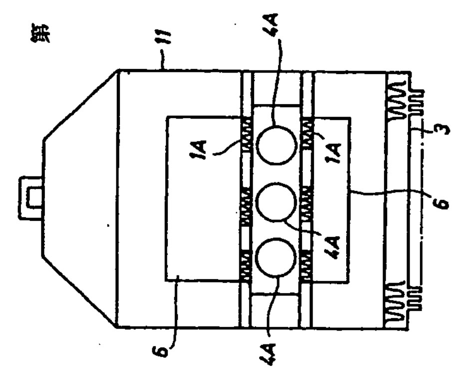
第4図

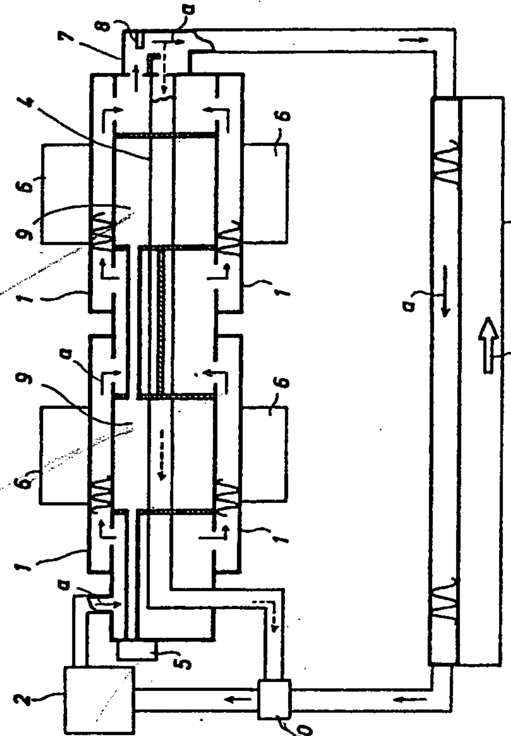


第1図



第2図





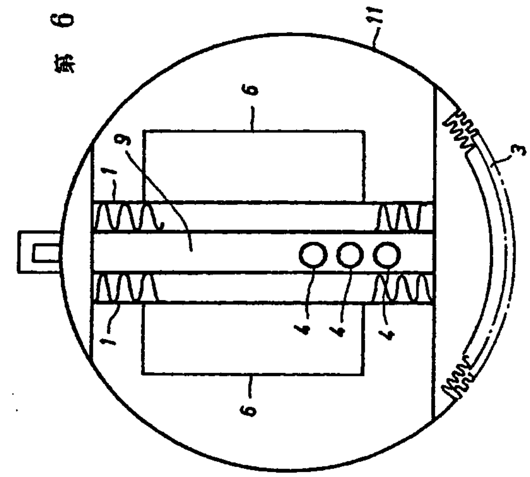
第5図

H_2O

H_2O

relief valve

check valve



第6図

PATENT
Attorney Docket No.: COOL-01500

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:	) Group Art Unit: 3744
Peng Zhou et al.	) Examiner: Zec, Filip
Serial No.: 10/643,638	) **RESPONSE TO OFFICE ACTION MAILED August 9, 2005**
Filed: August 18, 2003	)
For: **BOILING TEMPERATURE DESIGN IN PUMPED MICROCHANNEL COOLING LOOPS**	) 162 North Wolfe Road Sunnyvale, California 94086 (408) 530-9700

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

In response to the Office Action mailed August 9, 2005, please consider the remarks attached below.

Amendments to the Claims begin on page 2 of this paper.
Remarks begin on page 6 of this paper.

Amendments to the Claims

This listing of claims replaces all prior versions, and listings, of claims in the instant application.

1. (Amended) A method of cooling at least one heat-generating device using a cooling system, the method comprising the steps of:
using at least one pump to cause a fluid to flow in at least one heat exchanger; and
adjusting a pressure of the flowing fluid to correspondingly adjust a boiling point temperature of the fluid in the at least one heat exchanger.

2. (Original) The method of claim 1, wherein the step of adjusting a pressure of the fluid comprises adjusting operating conditions of the at least one pump in response to at least one of:
    changes in pressure of the fluid;
    changes in temperature of the fluid;
    changes in temperature of the at least one heat-generating device; and
    changes in temperature of the at least one heat exchanger.

3. (Original) The method of claim 1, wherein the step of adjusting a pressure of the fluid comprises adjusting an orifice coupled to the at least one heat exchanger in response to at least one of:
    changes in pressure of the fluid;
    changes in temperature of the fluid;
    changes in temperature of the at least one heat-generating device; and
    changes in temperature of the at least one heat exchanger.

4. (Original) The method of claim 1, wherein the method further comprises the step of:
providing at least one heat rejector for rejecting heat from the system to ambient air, the at least one heat rejector being situated downstream of the at least one heat exchanger.

5. (Original) The method of claim 4, wherein the method further comprises the step of providing a reservoir that accommodates a larger volume of a gas in the system generated during boiling.

6. (Original) The method of claim 5, wherein the reservoir reduces a change in pressure of the fluid that occurs during boiling.

7. (Original) The method of claim 5, wherein the reservoir is situated downstream of the at least one heat rejector..

8. (Original) The method of claim 5, wherein the reservoir is situated upstream of the at least one heat rejector.

9. (Original) The method of claim 5, wherein the reservoir having a volume region as great as the volume of vapor generated by the at least one heat exchanger during boiling of the fluid.

10. (Original) The method of claim 5, wherein the reservoir having an inlet coupled to a fluid outlet port of the at least one heat rejector via a first portion of a fluid transport line and an outlet coupled to a fluid inlet port of the at least one pump via a second portion of the fluid transport line.

11. (Original) The method of claim 5, wherein the reservoir is integrated with one of the at least one heat rejector and the at least one pump.

12. (Original) The method of claim 1, wherein the system is hermetically sealed.

13. (Original) The method of claim 12, wherein the hermetically sealed refers to a design in which the pressure under a given set of pump, ambient temperature, and heating conditions varies by less than 1 psi during a five year lifetime.

14. (Original) The method of claim 1, wherein the fluid is selected from a group consisting of water, acetonitrile, acetone, N-methylformamide, benzene, ethanol, methanol, and a combination thereof.

15. (Original) The method of claim 1, wherein the fluid comprises a halocarbon.

16. (Original) The method of claim 15, wherein the halocarbon is a methane series halocarbon selected from the group consisting of trichlorofluoromethane and trifluoromethane.

17. (Original) The method of claim 15, wherein the halocarbon is a ethane series halocarbon comprising pentafluoroethane (R-125).

18. (Original) The method of claim 1, wherein the fluid is a zeotropic blend comprising R-404A.

19. (Original) The method of claim 1, wherein the fluid is an azeotropic blend selected from the group consisting of R-500 and R-502.

20. (Original) The method of claim 1, wherein the fluid is inorganic.

21. (Original) The method of claim 20, wherein the inorganic is selected from the group consisting of ammonia and carbon dioxide.

22. (Original) The method of claim 1, wherein the fluid comprises a hydrocarbon.

23. (Original) The method of claim 22, wherein the hydrocarbon is selected from the group consisting of methane, ethane, propane, n-butane, 2-methylpropane, isobutane, ethene, ethylene, propene, propylene, and combinations thereof.

24. (Original) The method of claim 1, wherein the fluid is cryogenic.

25. (Original) The method of claim 24, wherein the cryogenic is selected from the group consisting of hydrogen, parahydrogen, helium, nitrogen, neon, air, oxygen, argon, and combinations thereof.

26. (Original) The method of claim 1, wherein the fluid is selected from the group consisting of water, acetonitrile, acetone, N-methylformamide, benzene, ethanol, methanol, halocarbons, zeotropic blends, azeotropic blends, inorganic fluids, hydrocarbons,

cryogenic fluids, and mixtures thereof, the halocarbons being methane series halocarbons selected from the group consisting of trichlorofluoromethane, trifluoromethane and mixtures thereof, the zeotropic blends comprising R-404A, the azeotropic blends being selected from the group consisting of R-500, R-502 and mixtures thereof, the inorganic fluids being selected from the group of ammonia, carbon dioxide and mixtures thereof, the hydrocarbons being selected from the group consisting of methane, ethane, propane, n-butane, 2-methylpropane, isobutane, ethene, ethylene, propene, propylene and mixtures thereof, the cryogenic fluids being selected from the group consisting of hydrogen, parahydrogen, helium, nitrogen, neon, air, oxygen, argon and mixtures thereof.

27. (Original) The method of claim 1, wherein the method further comprises the step of: providing sensors to adjust the fluid flow from the at least one pump.

28. (Original) The method of claim 27, wherein the sensors being coupled to the at least one heat exchanger.

29. (Original) The method of claim 1, wherein the at least one pump is electro-osmotic.

30. (Original) The method of claim 1, further comprising the step of: delivering to a catalytic recombiner a gaseous stream containing hydrogen being discharged from a downstream side of the at least one pump together with an amount of oxygen generated from an upstream side of the at least one pump sufficient to convert the hydrogen and oxygen to water, the catalytic recombiner coupled to an inlet port of the at least one pump.

31. (Original) The method of claim 1, wherein the step of adjusting a pressure of the fluid comprises adjusting the pressure of the fluid during a charging and sealing of the system.

32. (Original) The method of claim 1, wherein the step of adjusting a pressure of the fluid comprises adjusting at least one of a composition and volume and combinations thereof of at least one of a gas and liquid and combinations thereof introduced during charging of the system.

REMARKS

The Applicants respectfully request further examination and reconsideration in view of the above amendment and the remarks below. Previously, claims 1-32 were pending in the application, of those claims 1-32 were rejected. Claim 1 is amended above, and claims 1-32 are still pending.

Request for Consideration of Information Disclosure Statements

The Applicants respectfully request that the Examiner provide notice that several prior-filed Information Disclosure Statements ("IDS") were considered. Specifically, the Applicants have received no record that the six electronic IDS with EFS IDs 60085, 60086, 60087, and 60088, which were electronically filed on April 29, 2004; the electronic IDS with EFS ID 76815, which was electronically filed on January 26, 2005; and the electronic IDS with EFS ID 77188, which was electronically filed on February 1, 2005; have been considered. Accordingly, the applicants request that these IDS be considered and their consideration confirmed along with the next office action.

Claim Rejections Under 35 USC §103

Claims 1-32 stand rejected under 35 USC §103(a) as being unpatentable over "Modeling of Two-Phase Microchannel Heat Sinks for VLSI Chips" by Koo et al. ("Koo"), in view of at least Japanese Patent 01-256775 to Yamaguchi et al. ("Yamaguchi"). Several of claims are rejected in further view of one or more of the following: U.S. Patent 6,182,742 to Takahashi et al. ("Takahashi"), U.S. Patent Publication US 2003/0121274 to Wightman ("Wightman"), U.S. Patent Publication US 2004/0089008 to Tilton et al. ("Tilton"), U.S. Patent 6,775,996 to Cowans ("Cowans"), U.S. Patent Publication 2004/0040695 to Chesser et al. ("Chesser"), U.S. Patent 6,023,934 to Gold ("Gold"), and "A Closed-Loop Electroosmotic Microchannel Cooling System for VLSI Circuits" by Jiang et al. ("Jiang"). The Applicants respectfully traverse the rejections within the Office Action and submit that the various combinations of references relied upon within the Office Action do not make obvious the instant invention, as further outlined below.

The primary reference combination relied upon to show obviousness of the claimed invention was that of Koo in view of Yamaguchi as applied to claim 1.

The above amendment clarifies claim 1 to specifically recite that the pressure of "flowing fluid in the heat exchanger" is adjusted, e.g. adjustment takes place during operation of the heat exchanger. Within the Office Action, it is stated (FIG. references omitted),

> Koo discloses applicant's basic inventive concept, a method of cooling a heat-generating device using a pump to cause a fluid to flow in a heat exchanger and having a heat rejector, substantially as claimed.

The Office Action further contends,

> [Koo does not state] specifically that the pressure of the refrigerating fluid is adjusted in the system to correspondingly adjust the boiling point temperature of the fluid in the heat exchanger.

The literal teaching of figure 1 of Koo, disclosing an IC chip cooled by a microchannel heat exchanger through which fluid is pumped, can perform a method similar to that recited within the first subparagraph of claim 1: using a pump to cause fluid to flow in a heat exchanger. In this case, convective cooling occurs as shown by equation (6) of Koo and related discussion. However, Koo does not teach, hint or suggest that a pressure of the *flowing* fluid is adjusted to adjust a boiling point temperature of the fluid in the heat exchanger.

Further, Yamaguchi, as cited, also does not teach that a pressure of a *flowing* fluid within a cooling system is adjusted to correspondingly adjust a boiling point temperature of the fluid within a heat exchanger.

The cited portion of Yamaguchi describes a "cooling device" with "two *independent* cooling units, liquid and evaporation cooling units" [Applicants' emphasis] which includes a relief valve that "allows free adjustment of the boiling point of *the refrigerant for evaporation cooling* by changing the pressure of the refrigerant." Yamaguchi's boiling point adjustments rely on *evaporative* cooling, and there is no teaching or suggestion within the cited portion of Yamaguchi that such adjustment would be desirable or even effective in *convective* cooling. Accordingly, the cited portion of Yamaguchi does not include any teaching, hint or even a suggestion that the flowing fluid pressure be adjusted to correspondingly adjust the boiling point temperature of the fluid.

Therefore, the cited potion of Yamaguchi fails to establish that adjusting a pressure within a *convective* heat exchanger system to correspondingly adjust the boiling point within the system is old in the refrigeration art.

The requirements for establishing a *prima facie* case of obviousness are well settled, [MPEP §2143]

> To establish a *prima facie* case of obviousness, three basic criteria must be met. First, there must be some suggestion or motivation, either in the references themselves or in the knowledge generally available to one of ordinary skill in the art, to modify the reference or to combine reference teachings. Second, there must be a reasonable expectation of success. Finally, the prior art reference (or references when combined) must teach or suggest all the claim limitations. The teaching or suggestion to make the claimed combination and the reasonable

expectation of success must both be found in the prior art, and not based on applicant's disclosure.

Using the cited references, a *prima facie* case of obviousness has not been established. As shown above, as cited, Yamaguchi does not present a device that teaches or suggests the claim limitation expressed in subparagraph two of the first claim of the present invention: "adjusting a pressure of the flowing fluid to correspondingly adjust a boiling point temperature of the fluid in the at least one heat exchanger." Hence, the cited combination of Koo and Yamaguchi fails to teach or suggest all the claim limitations.

Specifically, claims 1 and 4 are rejected as being as being obvious over Koo in view of Yamaguchi. The amended claim 1 describes a method of cooling at least one heat-generating device using a cooling system. The method includes the steps of using at least one pump to cause a fluid to flow in at least one heat exchanger; and adjusting a pressure of the flowing fluid to correspondingly adjust a boiling point temperature of the fluid in the at least one heat exchanger. As described above, the cited combination of Koo and Yamaguchi does not teach or suggest a system in which a pressure of a flowing fluid is adjusted to correspondingly adjust a boiling point temperature. For at least these reasons, claim 1 is allowable over the teachings of Koo in view of Yamaguchi.

Claim 4 depends from claim 1, which is allowable over Koo in view of Yamaguchi for the reasons presented above. Thus, claim 4 is allowable as being dependent from an allowable base claim.

Claims 2, 27, and 28 are rejected over Koo in view of Yamaguchi as applied to claim 1 and further in view of Takahashi. Claims 2, 27 and 28 depend from claim 1, which is allowable over Koo in view of Yamaguchi for the reasons presented above. Thus, claims 2, 27, and 28 are allowable as being dependent from an allowable base claim.

Claims 3, 14-21, 26, 31, and 32 are rejected over Koo in view of Yamaguchi as applied to claim 1 and further in view of Wightman. Claims 3, 14-21, 26, 31, and 32 depend from claim 1, which is allowable over Koo in view of Yamaguchi for the reasons presented above. Thus, claims 3, 14-21, 26, 31, and 32 are allowable as being dependent from an allowable base claim.

Claims 5-7 and 9-11 are rejected over Koo in view of Yamaguchi and further in view of Tilton. Claims 5-7 and 9-11 depend from claim 1, which is allowable over Koo in view of Yamaguchi for the reasons presented above. Thus, claims 5-7 and 9-11 are allowable as being dependent from an allowable base claim.

Claim 8 rejected over Koo in view of Yamaguchi as applied to claim 1 and further in view of Tilton as applied to claim 5, and still further in view of Cowans. Claim 8 depends from claim 1, which is allowable over Koo in view of Yamaguchi for the reasons presented above. Thus, claim 8 is allowable as being dependent from an allowable base claim.

Claims 12 and 13 are rejected over Koo in view of Yamaguchi as applied to claim 1 and further in view of Chesser. Claims 12 and 13 depend from claim 1, which is allowable over Koo in view of Yamaguchi for the reasons presented above. Thus, claims 12 and 13 are allowable as being dependent from an allowable base claim.

Claims 22-25 are rejected over Koo in view of Yamaguchi as applied to claim 1 and further in view of Gold. Claims 22-25 depend from claim 1, which is allowable over Koo in view of Yamaguchi for the reasons presented above. Thus, claims 22-25 are allowable as being dependent from an allowable base claim.

Claims 29 and 30 are rejected over Koo in view of Yamaguchi as applied to claim 1 and further in view of Jiang. Claims 29 and 30 depend from claim 1, which is allowable over Koo in view of Yamaguchi for the reasons presented above. Thus, Claims 29 and 30 are allowable as being dependent from an allowable base claim.

For the reasons given above, the Applicant respectfully submits that the pending claims 1-32 are in a condition for allowance, and allowance at an early date would be appreciated. If the Examiner has any questions or comments, he is encouraged to call the undersigned at (408) 530-9700 so that any outstanding issues can be expeditiously resolved.

Respectfully submitted,
HAVERSTOCK & OWENS LLP

Dated: 11-9-05

By: Thomas B. Haverstock
Thomas B. Haverstock
Reg. No.: 32,571

Attorneys for Applicant

CERTIFICATE OF MAILING (37 CFR§ 1.8(a))

I hereby certify that this paper (along with any referred to as being attached or enclosed) is being deposited with the U.S. Postal Service on the date shown below with sufficient postage as first class mail in an envelope addressed to the: Commissioner for Patents, P.O. Box 1450 Alexandria, VA 22313-1450

HAVERSTOCK & OWENS LLP.

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/643,638	08/18/2003	Peng Zhou	COOL-01500	4432

28960 7590 01/10/2006

HAVERSTOCK & OWENS LLP
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JAN 13 2006

EXAMINER	
EARLY, MICHAEL JACOBY	
ART UNIT	**PAPER NUMBER**
3744	

DATE MAILED: 01/10/2006

docketed.

Please find below and/or attached an Office communication concerning this application or proceeding.

PTO-90C (Rev. 10/03)

Office Action Summary	Application No.	Applicant(s)	
	10/643,638	ZHOU ET AL.	
	Examiner	Art Unit	
	Michael J. Early	3744	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) OR THIRTY (30) DAYS, WHICHEVER IS LONGER, FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☒ Responsive to communication(s) filed on *14 November 2005*.

2a)☒ This action is **FINAL**. 2b)☐ This action is non-final.

3)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

4)☒ Claim(s) *1-32* is/are pending in the application.

4a) Of the above claim(s) _____ is/are withdrawn from consideration.

5)☐ Claim(s) _____ is/are allowed.

6)☒ Claim(s) *1-32* is/are rejected.

7)☐ Claim(s) _____ is/are objected to.

8)☐ Claim(s) _____ are subject to restriction and/or election requirement.

Application Papers

9)☐ The specification is objected to by the Examiner.

10)☐ The drawing(s) filed on _____ is/are: a)☐ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

11)☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

Priority under 35 U.S.C. § 119

12)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a)☐ All b)☐ Some * c)☐ None of:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☐ Notice of References Cited (PTO-892)

2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)

3) ☒ Information Disclosure Statement(s) (PTO-1449 or PTO/SB/08) Paper No(s)/Mail Date *4/29/04; 1/26/05;* .

4) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____ .

5) ☐ Notice of Informal Patent Application (PTO-152)

6) ☒ Other: *PTO-1449 or PTO/SB/08 (2/1/05)*.

DETAILED ACTION

Claim Rejections – 35 USC § 103

The following is a quotation of 35 U.S.C. 103(a) which form the basis for all obviousness rejections set forth in this Office action:

> (a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.

Claims 1 and 4 are rejected under 35 U.S.C. 103(a) as being unpatentable over Koo et al. ("Modeling of Two-phase microchannel Heat Sinks for VLSI Chips"), in view of Yamaguchi (JP 01-256775).

Koo et al. discloses applicant's basic inventive concept, a method of cooling a heat-generating device (IC Chip, Figure 1), using a pump (Electrokinetic pump, Figure 1) to cause a fluid flow in a heat exchanger (Microchannel Heat Exchanger, Figure 1) and having a heat rejector (Condenser, Figure 1) for rejecting heat from the system, located downstream from the heat exchanger. Koo et al. further disclose that both the pressure drop and pump power are dependent upon the mass flowrate of the flowing fluid within the system (see page 425, last paragraph).

However, Koo et al. do not disclose:

- the pressure of the refrigerating fluid is adjusted in the system to correspondingly adjust the boiling point temperature of the fluid in the heat exchanger.

Yamaguchi teaches that adjusting the pressure of the refrigerating fluid in the heat exchanger will correspondingly adjust the boiling point temperature of the refrigerant for evaporation cooling, via a relief valve (5), to be old in the refrigeration art (see constitution).

Therefore, it would have been obvious to one having ordinary skill in the art at the time the invention was made to modify the system of Koo et al., by adjusting the pressure of the refrigerating fluid to correspondingly adjust the boiling point temperature of the refrigerant, as taught by Yamaguchi, in order to: provide efficient cooling of the system and permit higher fluid temperatures, which in turn would maximize the heat exchanging capability of the apparatus (see constitution).

Claims 2, 27 and 28 rejected under 35 U.S.C. 103(a) as being unpatentable over Koo et al., in view of Yamaguchi, as applied to claim 1 above, and further in view of Takahashi et al. (U.S. 6,182,742).

However, Koo et al. in view of Yamaguchi do not disclose:

- the pressure of the refrigerating fluid is adjusted in the system by adjusting the operating conditions of the pump in response to the change in the temperature of the fluid.

Takahashi et al. teach adjusting pressure of the refrigerating fluid in the system by adjusting the operating conditions of the pump in response to the change in the temperature of the fluid (temperature sensors, located at the distribution header, prior to entering the heat exchanger; col. 7, lines 15 – 22 and col. 8, lines 12 – 18) to be old in the refrigeration art.

Therefore, it would have been obvious to one having ordinary skill in the art at the time the invention was made to modify the system of Koo et al. in view of Yamaguchi, by adjusting the operating conditions of the pump in response to the change in the temperature of the fluid, as taught by Takahashi, in order to adjust the pressure of the refrigerating fluid in the system prior to it entering the heat exchanger.

Claims 3, 14 – 21, 26, 31 and 32 are rejected under 35 U.S.C. 103(a) as being unpatentable over Koo et al., in view of Yamaguchi, as applied to claim 1 above, and further in view of Wightman (U.S. 2003/0121274).

However, Koo et al. in view of Yamaguchi do not disclose:

- the pressure of the refrigerating fluid is adjusted in the system by adjusting an orifice coupled to the heat exchanger in response to the change in the temperature of the fluid.

Wightman shows adjusting pressure of the refrigerating fluid in the system by adjusting an orifice (18, Figure 1) coupled to the heat exchanger (14, Figure 1) in response to the change in the temperature of the fluid (32) to be old in the refrigeration art.

Therefore, it would have been obvious to one having ordinary skill in the art at the time the invention was made to modify the system of Koo et al. in view of Yamaguchi, by adjusting pressure of the refrigerating fluid in the system by adjusting an orifice coupled to the heat exchanger prior to it entering the heat exchanger, but based on the temperature of the fluid after the heat exchanger with the heat generating device, as taught by Wightman, in order to have a precise and rapid response of the orifice to variations in volumetric expansion rate [0005].

Also, Koo et al. in view of Yamaguchi do not disclose a particular type of refrigerant used, be it water, trichlorofluoromethane (R-23), pentafluoromethane (R-125), a zeotropic blend comprising R-404a, an azeotropic blend consisting of R-500 and R-502, or ammonia, as claimed by the applicant. Wightman shows that water, trichlorofluoromethane (R-23), pentafluoromethane (R-125), a zeotropic blend comprising R-404a, an azeotropic blend consisting of R-500 and R-502, or ammonia (0046), to be refrigerants common in the refrigeration art.

Therefore, it would have been obvious to one having ordinary skill in the art at the time the invention was made to modify the system of Koo et al. in view of Yamaguchi, by specifying the type of refrigerant used, as taught by Wightman, in order to make the product more user- and environment-friendly.

Claims 5 – 7 and 9 – 11 are rejected under 35 U.S.C. 103(a) as being unpatentable over Koo et al., in view of Yamaguchi, as applied to claim 1 above, and further in view of Tilton et al. (U.S. 2004/0089008).

However, Koo et al. in view of Yamaguchi do not disclose:

- the use of a reservoir to accommodate gas generated during boiling and reduce the change in pressure, said reservoir being downstream from the hear rejector and upstream from the pump.

Tilton et al. teach the use of a reservoir (25, Figure 2) to accommodate gas generated during boiling and reduce the change in pressure, said reservoir being downstream from the hear rejector (30, Figure 2) and upstream from the pump (40, Figure 2) to be old in the refrigeration art. Also, since the reservoir is used to store the vapor, it would be an obvious design choice to have such tank at a sufficient volume to contain the maximum amount of gas generated in the heat exchanger. Finally, the applicant is reminded that the use of a one piece construction instead of the structure disclosed in Tilton et al. would be merely a matter of obvious engineering choice, In re Larson, 340 F.2d 965, 968, 144 USPQ 347, 349 (CCPA 1965).

Therefore, it would have been obvious to one having ordinary skill in the art at the time the invention was made to modify the system of Koo et al. in view of Yamaguchi, by using a reservoir, integral with the heat rejector and the pump, as taught by Tilton et al., to accommodate gas generated during boiling in order to reduce the change in pressure and prevent possible pump cavitation [0053].

Claim 8 is rejected under 35 U.S.C. 103(a) as being unpatentable over Koo et al., in view of Yamaguchi, as applied to claim 1 above, and further in view of Tilton et al., as applied to claim 5 above and still further in view of Cowans (U.S. 6,775,996).

Koo et al. in view of Yamaguchi and further in view of Tilton et al. do not discloses:

- the reservoir is upstream of the heat rejector.

Cowans teaches the use of a reservoir (92, Figure 2) to accommodate gas generated during boiling, said reservoir being upstream from the hear rejector (44, Figure 2) to be old in the refrigeration art.

Therefore, it would have been obvious to one having ordinary skill in the art at the time the invention was made to modify the system of Koo et al. in view of Yamaguchi and further in view of Tilton et al., by using a reservoir to accommodate gas generated during boiling upstream of the heat rejector, as taught by Cowans, in order to use the gas as a heat exchanging fluid for another purpose (subcooler 52, Figure 2).

Claims 12 and 13 are rejected under 35 U.S.C. 103(a) as being unpatentable over Koo et al., in view of Yamaguchi, as applied to claim 1 above, and further in view of Chesser et al. (U.S. 2004/0040695).

However, Koo et al. in view of Yamaguchi do not disclose:

- the system is hermetically sealed, where the pressure varies less than 1 psi during a five year lifetime.

Chesser et al. teach the use of a hermetically sealed pumped loop cooling system [0042] to be old in the refrigeration art. Also, any hermetically sealed system is completely sealed, which provides no variations in the pressure, including a change in pressure of 1 psi.

Therefore, it would have been obvious to one having ordinary skill in the art at the time the invention was made to modify the system of Koo et al. in view of Yamaguchi, by using a hermetically sealed pumped loop cooling system, as taught by Chesser et al., in order to prevent outside elements from factoring in the cooling variations and the systems performance (sub-atmospheric conditions, [0042]).

Claims 22 – 25 are rejected under 35 U.S.C. 103(a) as being unpatentable over Koo et al., in view of Yamaguchi, as applied to claim I above, and further in view of Gold (U.S. 6,023,934).

However, Koo et al. in view of Yamaguchi do not disclose:

- a particular type of refrigerant used, be it a hydrocarbon like methane, or a cryogenic like helium.

Gold teaches the use of a hydrocarbon like methane (see col. 4, line 12), or a cryogenic like helium (see col. 1, lines 18 – 19) as a refrigerant to be old in the refrigeration art.

Therefore, it would have been obvious to one having ordinary skill in the art at the time the invention was made to modify the system of Koo et al. in view of Yamaguchi, by specifying the type of refrigerant used, as taught by Gold, in order to make the product more user- and environment-friendly.

Claims 29 and 30 are rejected under 35 U.S.C. 103(a) as being unpatentable over Koo et al., in view of Yamaguchi, as applied to claim 1 above, and further in view of Kiang et al. ("A Closed-Loop Electroosmotic Microchannel Cooling System for VLSI Circuits").

However, Koo et al. in view of Yamaguchi do not disclose:

- using an electroosmotic pump as pumping means and a catalytic recombiner, coupled to the inlet port of the pump, wherein the hydrogen and oxygen are combined to produce water.

Jiang et al. teach the use of an electroosmotic pump (see page 4, lines 6 – 8) as pumping means and a catalytic recombiner (as seen in Figure 8) to be old in the refrigeration art.

Therefore, it would have been obvious to one having ordinary skill in the art at the time the invention was made to modify the system of Koo et al. in view of Yamaguchi, by using an electroosmotic pump as pumping means, as taught by Jiang et al., since electroosmotic pumps do not require any movable parts and are very compact (see page 4, line 8), and a catalytic recombiner, coupled to the inlet port of the pump in order to recombine the gas during electrolysis (see page 9, lines 1 – 2).

Response to Arguments

Applicant's arguments filed 11/14/05 have been fully considered but they are not persuasive.

The applicant states that Yamaguchi's boiling point adjustments rely on evaporative cooling, and thus do not teach or suggest that such adjustment would be desirable or even effective in convective cooling. This argument is not persuasive because the distinction between evaporative and convective cooling is not stated in the claim.

The applicant states that Yamaguchi does not teach, hint or suggest that the flowing fluid pressure be adjusted to correspondingly adjust the boiling point temperature of the fluid. This argument is correct; however, the combination of Koo et al. in view of Yamaguchi does provide this teaching.

Although Yamaguchi teaches of stopping a circulating pump before allowing the boiling point of the refrigerant to be adjusted by the pressure of the refrigerant, Koo et al. disclose of a method of cooling a heat-generating device with a pump ***to cause fluid to flow*** in a heat exchanger and having a heat rejecter. Thus for one of ordinary skill in the art at the time of the invention, the combined teaching would have been sufficient to meet the claim.

Conclusion

THIS ACTION IS MADE FINAL. Applicant is reminded of the extension of time policy as set forth in 37 CFR 1.136(a).

A shortened statutory period for reply to this final action is set to expire THREE MONTHS from the mailing date of this action. In the event a first reply is filed within TWO MONTHS of the mailing date of this final action and the advisory action is not mailed until after the end of the THREE MONTH shortened statutory period, then the shortened statutory period will expire on the date the advisory action is mailed, and any extension fee pursuant to 37 CFR 1.136(a) will be calculated from the mailing date of the advisory action. In no event, however, will the statutory period for reply expire later than SIX MONTHS from the mailing date of this final action.

Any inquiry concerning this communication or earlier communications from the examiner should be directed to Michael J. Early whose telephone number is (571) 272-3681. The examiner can normally be reached on Monday - Friday, 7am - 4:30pm.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Cheryl Tyler can be reached on (571) 272-4834. The fax phone number for the organization where this application or proceeding is assigned is (571) 273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free).

MJE
1/6/06

Michael J. Early
Patent Examiner
Art Unit 3744

CHERYL TYLER
SUPERVISORY PATENT EXAMINE

To:	Mr. Thomas Haverstock	**From:**	Examiner Early (USPTO)
Fax:	408.530.9797	**Pages:**	8 (including cover page)
Phone:	408.530.9700	**Date:**	2/28/2006
Re:	Serial #: 10/643,638	**CC:**	

☐ **Urgent** ☒ **For Review** ☐ **Please Comment** ☐ **Please Reply** ☐ **Please Recycle**

- **Comments:**

Mr. Havenstock,
This fax is in reference to a phone interview conducted on 2/15/06, which regarded a patent application recently submitted (Serial #: 10/643,368 and Attorney docket #: COOL-01500). Attached is an English translation of the Japanese Patent 01-256775, per your request.

Regards,
Mike Early

Michael J. Early
Patent Examiner -- Art Unit 3744
U.S. Patent and Trademark Office
401 Dulany Street -- Randolph Building
Alexandria, VA 22313-1450
571.272.3681

PTO: 2006-2767
Japanese Published Unexamined (Kokai) Patent Publication No. 01-256775; Publication Date: October 13, 1989; Application No. 63-082669; Application Date: April 4, 1988; Int. Cl.[4]: F25D 9/00 B64D 13/08; Inventor: Toshiaki Yamaguchi; Applicant: Mitsubishi electric Corporation; Japanese Title: Poddo Reikyaku Souchi (Pod Cooling Apparatus)

Specification

1. Title of Invention

Pod Cooling Apparatus

2. Claim

A pod cooling apparatus, characterized by being comprised of a cold plate that cools electronics, a circulating pump that sends a circulating coolant for cooling the cold plate, an outer plate heat exchanger that cools the circulating coolant using ram air, a boiling and cooling heat exchanger for cooling the cold plate by a boiling and cooling system when the cold plate cannot be cooled by a liquid cooling means using the circulating coolant, and a relief valve that exhausts a vaporized boiling and cooling coolant and that controls the pressure.

3. Detailed Description of the Invention

[Field of Industrial Application]

This invention pertains to a cooling apparatus for controlling the temperature of electronics within a pod that is mounted under the body or [illegible] of an aircraft.

[Prior Art]

Fig.5 and Fig.6 are cross-sectional views illustrating prior art pod cooling apparatus. In the drawings, reference number 1 refers to a cold plate that mounts electronics 6; 2 to a circulating pump that circulates a coolant a; 3 to an outer plate heat exchanger for reducing the temperature of a circulation coolant a; 4 to a boiling and cooling heat exchanger; 5 to a relief valve that exhausts a vaporized coolant; 7 to a bypass valve for sending the coolant a to the outer plate heat exchanger 3 or the boiling and cooling heat exchanger 4; 8 to a temperature sensor that detects the temperature of the coolant a in the bypass valve 7; 9 to a water tank that contains water used for boiling and cooling operations; 10 to a check valve; and 11 to a pod body.

The operation is described next. The performance of the outer plate heat exchanger 3 varies by the flight conditions of the aircraft as it heat-exchanges using ram air b. First, the temperature of circulation coolant a is detected with the temperature sensor 8. When the temperature of the circulation coolant a is low, a heat exchange is performed using a liquid cooling system with the outer plate heat exchanger 3. As the temperature increases, the heat exchange is operated using a boiling and cooling system at higher cooling performance. At the liquid cooling system, as shown in Fig.5 by a solid line arrow, the coolant a is sent using the circulating pump 2 and passes through the cold plate 1 with the electronics 6 mounted to rob the heat. The heated coolant a is sent to the outer plate heat exchanger 3 to be cooled with the ram air b. The cooled coolant a is sent to the cold plate 1 again. If the performance of the outer plate heat exchanger 3 deteriorates to increase the temperature of the coolant a, as shown in Fig.5 by a dashed line arrow, the coolant 5 is sent from the bypass valve 7 to the boiling and cooling heat exchanger 4. At this point, the coolant a applies a heat exchange by evaporating water

inside the water tank 9 to be cooled. The cooled coolant a is sent to the cold plate 1 via the check valve 10. Evaporated water is exhausted via the relief valve 5. Thereby, the cooling period relies on the amount of water.

[Problem to Be Solved by the Invention]

As prior art pod cooling apparatus is constituted as described above, the bypass valve 7 for substituting the cooling system by the temperature of the coolant a is required. As a result, the apparatus becomes larger and more complicated.

The present invention is produced so as to eliminate the aforementioned disadvantages and aims to obtain a light and compact pod cooling apparatus.

[Measures for Solving the Problem]

According to the pod cooling apparatus of the invention, the devices for liquid cooling and boiling and cooling are separated. At the boiling and cooling, the cold plate is directly cooled instead of cooling it by cooling the circulating coolant.

[Effect]

The bypass valve is not required for the pod cooling apparatus of the invention because of the separation of the boiling and cooling device form the liquid cooling device. Thereby, the circulating pump does not need to be operated at a boiling and cooling to make the heat generation of the pump zero.

[Working Example(s) of the Invention]

A working example of the invention is described with reference to Fig.1 and Fig.2. Fig.1 is a vertical cross-sectional side view of the working example, and Fig.2 a vertical cross-sectional front view thereof. The description is omitted by providing the same reference number to the same or equivalent component as in prior art apparatus. In the drawings, reference number 1A refers to a cold plate that mounts the electronics 6, which is provided at two pieces in parallel at upper and lower rows. Reference number 4A refers to a boiling and cooling heat exchanger that is arranged between the cold plates 1A.

The operation of the working example is described next. At the liquid cooling system, the circulation coolant a output from a circulating pump 2 cools electronics 6 by a heat exchange means when it passes through the cold plates 1A. The circulation coolant a whose temperature has increased is cooled while being heat-exchanged with ram air b at an outer plate heat exchanger 3 and then sent to the cold plates 1A again. If the temperature of the electronics 6 increases to exceed a predetermined temperature as the performance of the outer plate heat exchanger 3 deteriorates, a circulating pump 2 stops. Using a vaporization heat generated by boiling the coolant in the boiling and cooling heat exchanger 4A, the cold plates 1A are directly cooled. The boiled coolant is exhausted from a relief valve 5. Thereby, the cooling period relies on the amount of the coolant in the boiling and cooling heat exchanger 4A.

Because of the use of the relied valve 5, the pressure of the boiling and cooling coolant is made be varied to freely control the boiling point of the coolant.

As in the working example, the boiling and cooling heat exchanger 4A is inserted between the cold plates 1A. As shown in Fig.3, a flow passage 1a that passes a circulation

coolant by the liquid cooling system and a boiling and cooling heat exchanger 4B can also be provided on serially arranged cold plates 1B. As shown in Fig.4, a liquid cooling heat exchanger 12 can be provided inside a boiling and cooling heat exchanger 40 without providing the flow passage 1a that passes the circulation coolant in the cold plates 1A.

Furthermore, a flow passage that passes a circulation coolant for cooling cold plates used at the liquid cooling system can be used during a boiling and cooling as well without particularly providing a boiling and cooling heat exchanger so as to boil the circulation coolant.

[Advantageous Effect of the Invention]

As described above, according to the invention, the cold plate is directly cooled during the boiling and cooling, thereby reducing the size of the apparatus and simplifying the structure.

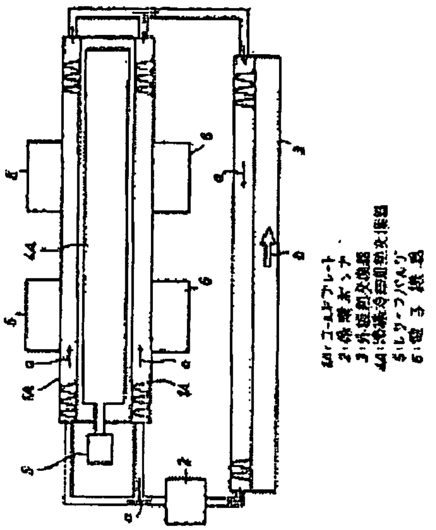
4. Brief Description of the Drawings

Fig.1 is a vertical cross-sectional side view illustrating a pod cooing apparatus as in a working example of the invention. Fig.2 is a vertical cross-sectional front view illustrating the working example. Fig.3 and Fig.4 are vertical cross-sectional front views illustrating other working examples of the invention. Fig.5 is a vertical cross-sectional side view illustrating prior art pod cooling apparatus. Fig.6 is a vertical cross-sectional front view illustrating the pod cooling apparatus.

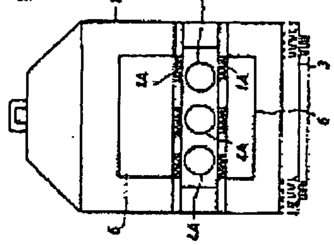
In the drawings, reference number 1A refers to a cold plate; 2 to a circulating pump; 3 to an outer plate heat exchanger; 4A to a boiling and cooling heat exchanger; 5 to a relief valve; and 6 to electronics.

The same reference numbers refer to the same or equivalent components.

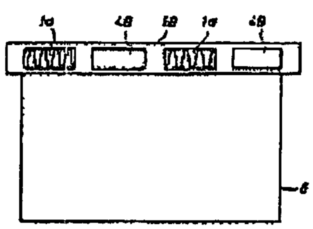
第 1 図



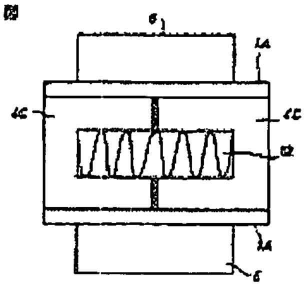
第 2 図

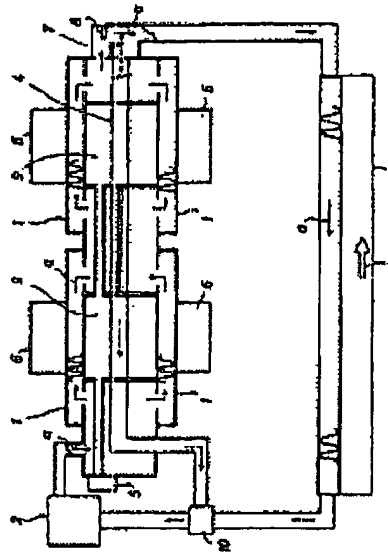


第 3 図

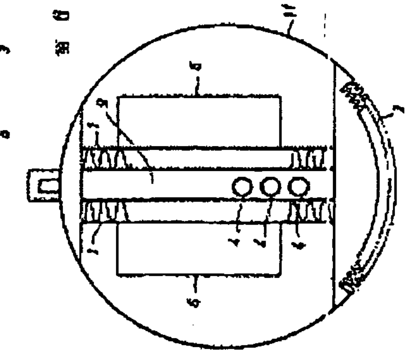


第 4 図





第5図



第6図

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/643,638	08/18/2003	Peng Zhou	COOL-01500	4432

28960 7590 02/22/2006

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EXAMINER	
EARLY, MICHAEL JACOBY	
ART UNIT	**PAPER NUMBER**
3744	

DATE MAILED: 02/22/2006

Please find below and/or attached an Office communication concerning this application or proceeding.

Interview Summary	Application No.	Applicant(s)
	10/643,638	ZHOU ET AL.
	Examiner	**Art Unit**
	Michael J. Early	3744

All participants (applicant, applicant's representative, PTO personnel):

(1) *Michael J. Early*. (3)_____.

(2) *Cheryl Tyler*. (4)_____.

Date of Interview: *15 February 2006*.

Type: a)☒ Telephonic b)☐ Video Conference
c)☐ Personal [copy given to: 1)☐ applicant 2)☐ applicant's representative]

Exhibit shown or demonstration conducted: d)☐ Yes e)☒ No.
If Yes, brief description: _____.

Claim(s) discussed: *1*.

Identification of prior art discussed: *Yes*.

Agreement with respect to the claims f)☐ was reached. g)☒ was not reached. h)☐ N/A.

Substance of Interview including description of the general nature of what was agreed to if an agreement was reached, or any other comments: *See Continuation Sheet*.

(A fuller description, if necessary, and a copy of the amendments which the examiner agreed would render the claims allowable, if available, must be attached. Also, where no copy of the amendments that would render the claims allowable is available, a summary thereof must be attached.)

THE FORMAL WRITTEN REPLY TO THE LAST OFFICE ACTION MUST INCLUDE THE SUBSTANCE OF THE INTERVIEW. (See MPEP Section 713.04). If a reply to the last Office action has already been filed, APPLICANT IS GIVEN A NON-EXTENDABLE PERIOD OF THE LONGER OF ONE MONTH OR THIRTY DAYS FROM THIS INTERVIEW DATE, OR THE MAILING DATE OF THIS INTERVIEW SUMMARY FORM, WHICHEVER IS LATER, TO FILE A STATEMENT OF THE SUBSTANCE OF THE INTERVIEW. See Summary of Record of Interview requirements on reverse side or on attached sheet.

Examiner Note: You must sign this form unless it is an Attachment to a signed Office action.

Examiner's signature, if required

Summary of Record of Interview Requirements

Manual of Patent Examining Procedure (MPEP), Section 713.04, Substance of Interview Must be Made of Record
A complete written statement as to the substance of any face-to-face, video conference, or telephone interview with regard to an application must be made of record in the application whether or not an agreement with the examiner was reached at the interview.

Title 37 Code of Federal Regulations (CFR) § 1.133 Interviews
Paragraph (b)
In every instance where reconsideration is requested in view of an interview with an examiner, a complete written statement of the reasons presented at the interview as warranting favorable action must be filed by the applicant. An interview does not remove the necessity for reply to Office action as specified in §§ 1.111, 1.135. (35 U.S.C. 132)

37 CFR §1.2 Business to be transacted in writing.
All business with the Patent or Trademark Office should be transacted in writing. The personal attendance of applicants or their attorneys or agents at the Patent and Trademark Office is unnecessary. The action of the Patent and Trademark Office will be based exclusively on the written record in the Office. No attention will be paid to any alleged oral promise, stipulation, or understanding in relation to which there is disagreement or doubt.

The action of the Patent and Trademark Office cannot be based exclusively on the written record in the Office if that record is itself incomplete through the failure to record the substance of interviews.

It is the responsibility of the applicant or the attorney or agent to make the substance of an interview of record in the application file, unless the examiner indicates he or she will do so. It is the examiner's responsibility to see that such a record is made and to correct material inaccuracies which bear directly on the question of patentability.

Examiners must complete an Interview Summary Form for each interview held where a matter of substance has been discussed during the interview by checking the appropriate boxes and filling in the blanks. Discussions regarding only procedural matters, directed solely to restriction requirements for which interview recordation is otherwise provided for in Section 812.01 of the Manual of Patent Examining Procedure, or pointing out typographical errors or unreadable script in Office actions or the like, are excluded from the interview recordation procedures below. Where the substance of an interview is completely recorded in an Examiners Amendment, no separate Interview Summary Record is required.

The Interview Summary Form shall be given an appropriate Paper No., placed in the right hand portion of the file, and listed on the "Contents" section of the file wrapper. In a personal interview, a duplicate of the Form is given to the applicant (or attorney or agent) at the conclusion of the interview. In the case of a telephone or video-conference interview, the copy is mailed to the applicant's correspondence address either with or prior to the next official communication. If additional correspondence from the examiner is not likely before an allowance or if other circumstances dictate, the Form should be mailed promptly after the interview rather than with the next official communication.

The Form provides for recordation of the following information:

- Application Number (Series Code and Serial Number)
- Name of applicant
- Name of examiner
- Date of interview
- Type of interview (telephonic, video-conference, or personal)
- Name of participant(s) (applicant, attorney or agent, examiner, other PTO personnel, etc.)
- An indication whether or not an exhibit was shown or a demonstration conducted
- An identification of the specific prior art discussed
- An indication whether an agreement was reached and if so, a description of the general nature of the agreement (may be by attachment of a copy of amendments or claims agreed as being allowable). Note: Agreement as to allowability is tentative and does not restrict further action by the examiner to the contrary.
- The signature of the examiner who conducted the interview (if Form is not an attachment to a signed Office action)

It is desirable that the examiner orally remind the applicant of his or her obligation to record the substance of the interview of each case. It should be noted, however, that the Interview Summary Form will not normally be considered a complete and proper recordation of the interview unless it includes, or is supplemented by the applicant or the examiner to include, all of the applicable items required below concerning the substance of the interview.

A complete and proper recordation of the substance of any interview should include at least the following applicable items:

1) A brief description of the nature of any exhibit shown or any demonstration conducted,
2) an identification of the claims discussed,
3) an identification of the specific prior art discussed,
4) an identification of the principal proposed amendments of a substantive nature discussed, unless these are already described on the Interview Summary Form completed by the Examiner,
5) a brief identification of the general thrust of the principal arguments presented to the examiner,
   (The identification of arguments need not be lengthy or elaborate. A verbatim or highly detailed description of the arguments is not required. The identification of the arguments is sufficient if the general nature or thrust of the principal arguments made to the examiner can be understood in the context of the application file. Of course, the applicant may desire to emphasize and fully describe those arguments which he or she feels were or might be persuasive to the examiner.)
6) a general indication of any other pertinent matters discussed, and
7) if appropriate, the general results or outcome of the interview unless already described in the Interview Summary Form completed by the examiner.

Examiners are expected to carefully review the applicant's record of the substance of an interview. If the record is not complete and accurate, the examiner will give the applicant an extendable one month time period to correct the record.

Examiner to Check for Accuracy

If the claims are allowable for other reasons of record, the examiner should send a letter setting forth the examiner's version of the statement attributed to him or her. If the record is complete and accurate, the examiner should place the indication, "Interview Record OK" on the paper recording the substance of the interview along with the date and the examiner's initials.

Continuation of Substance of Interview including description of the general nature of what was agreed to if an agreement was reached, or any other comments: The interview focused on Claim 1 and the two references which were used to rejection the claim (Koo et al. -- "Modeling of Two-phase microchannel Heat Sinks for VLSI Chips"; Yamaguchi -- JP 01-256775). The applicant's attorneys inquired about the references' combined teaching and their basis for rejection. It was agreed that upon obtaining an English translation of the Yamaguchi reference, a final decision will be made in regard to the applicant's arguments.

Cheryl J. Tyler

CHERYL TYLER
SUPERVISORY PATENT EXAMINER